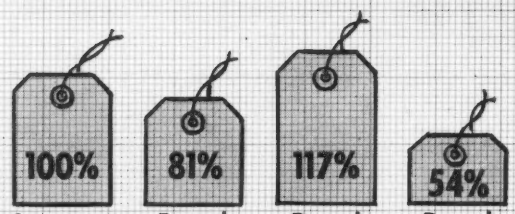
Corrosion

YOU CAN'T KNOW
what the real price tag is...

How price per gallon compares on leading vinyls



UNLESS YOU
compare mil sq. ft. per gallon and...

Sq. ft. coverage per gallon, 1 mil thick

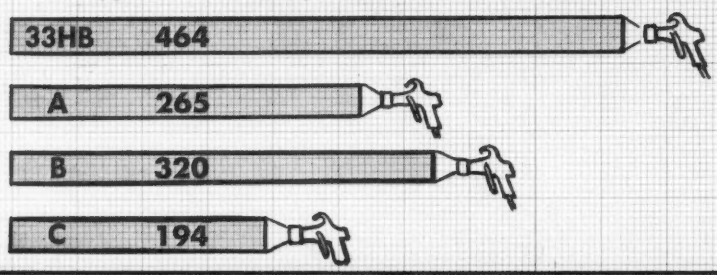
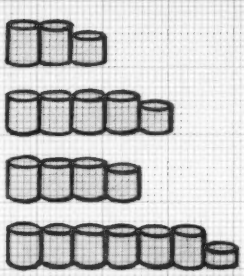


FIGURE THE
material cost of each coating, then get the...

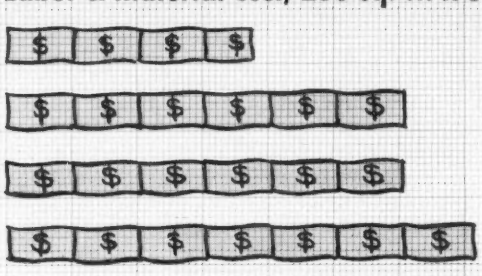
Needed to coat 250 sq. ft. 5 mils thick



	GALS.	COST
33HB	2.68	$17.37
A	4.72	24.78
B	3.91	29.72
C	6.44	22.54

REAL COST
by adding labor for the number of coats needed.

Labor & material cost, 250 sq. ft. x 5 mils thick



33HB	$37.47
A	60.18
B	59.05
C	70.84

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Amercoat 33HB now gives you even *more* "mils per gallon" —and at the lowest cost of any leading vinyl!

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New Lower Cost

In evaluating any coating, always look at the cost per square foot, and the number of coats required to build proper film thickness. 33HB is nearly 24% cheaper per mil square foot than traditionally low cost 33... and compared to other leading vinyls, (see chart) savings are even greater. For example, although the gallon price of Coating "C" is 46% lower than 33HB, because of its low solids content the actual *material* cost for 5 mils thickness is almost 30% higher than 33HB, and the applied cost, (labor and material) is almost 90% higher.

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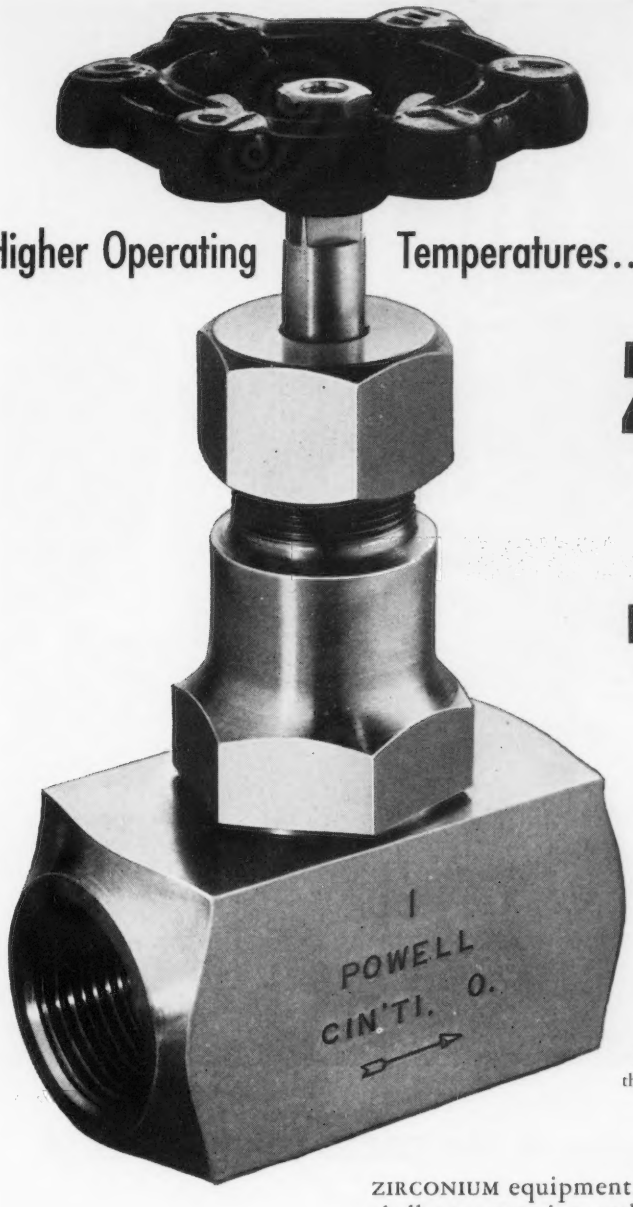

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devoted entirely to corrosion research and control

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AMENDMENTS TO NACE ARTICLES AND BY-LAWS

The Articles of Organization and By-Laws of the National Association of Corrosion Engineers were published in the March 1952 issue of CORROSION. Since that time three amendments have been made in the by-laws as follows:

1. At a meeting on March 19, 1954 the board of directors approved an amendment to the NACE by-laws increasing active membership dues from $7.50 to $10.00. The amendment, effective January 1, 1955 was to Section 1, Article 11, of the by-laws that became effective March 11, 1951.
2. At a meeting on December 3, 1954 the board of directors approved a recommendation of the Policy and Planning Committee amending Section 2, Article I, of the NACE by-laws that became effective March 11, 1951 as folows:
   All Applications for membership shall be forwarded to the Secretary and upon a finding by the Secretary that an applicant's qualifications conform with standards and membership requirements of the Association, membership shall become effective immediately upon payment of dues. If in the judgment of the Secretary, the eligibility of any applicant for membership shall be uncertain, such applicant's application shall be referred by the Secretary to the Executive Committee and an affirmative vote of a majority thereof required for election to membership.
3. The Board of Directors by letter ballot dated April 25, 1956, approved an amendment to the NACE by-laws consisting of the addition of a new paragraph designated as Section 5, Article III, of the By-Laws that became effective March 11, 1951:
   Exhibitions held or sponsored by regions or sections shall have the approval of and be under the management of the Board of Directors including the handling of formal contacts with prospective exhibitors and contracts for exhibit space by the Executive Secretary of NACE. The proceeds from such exhibitions shall become a part of the funds of the Association.

THIS MONTH'S COVER—Sidney Sussman, chief chemist and Harry L. Shuldener, president of Water Service Laboratories, New York are shown in the firm's Corrosion Research Exhibit, which includes samples from actual installations showing the serious effects that can be expected from short term corrosion attack.

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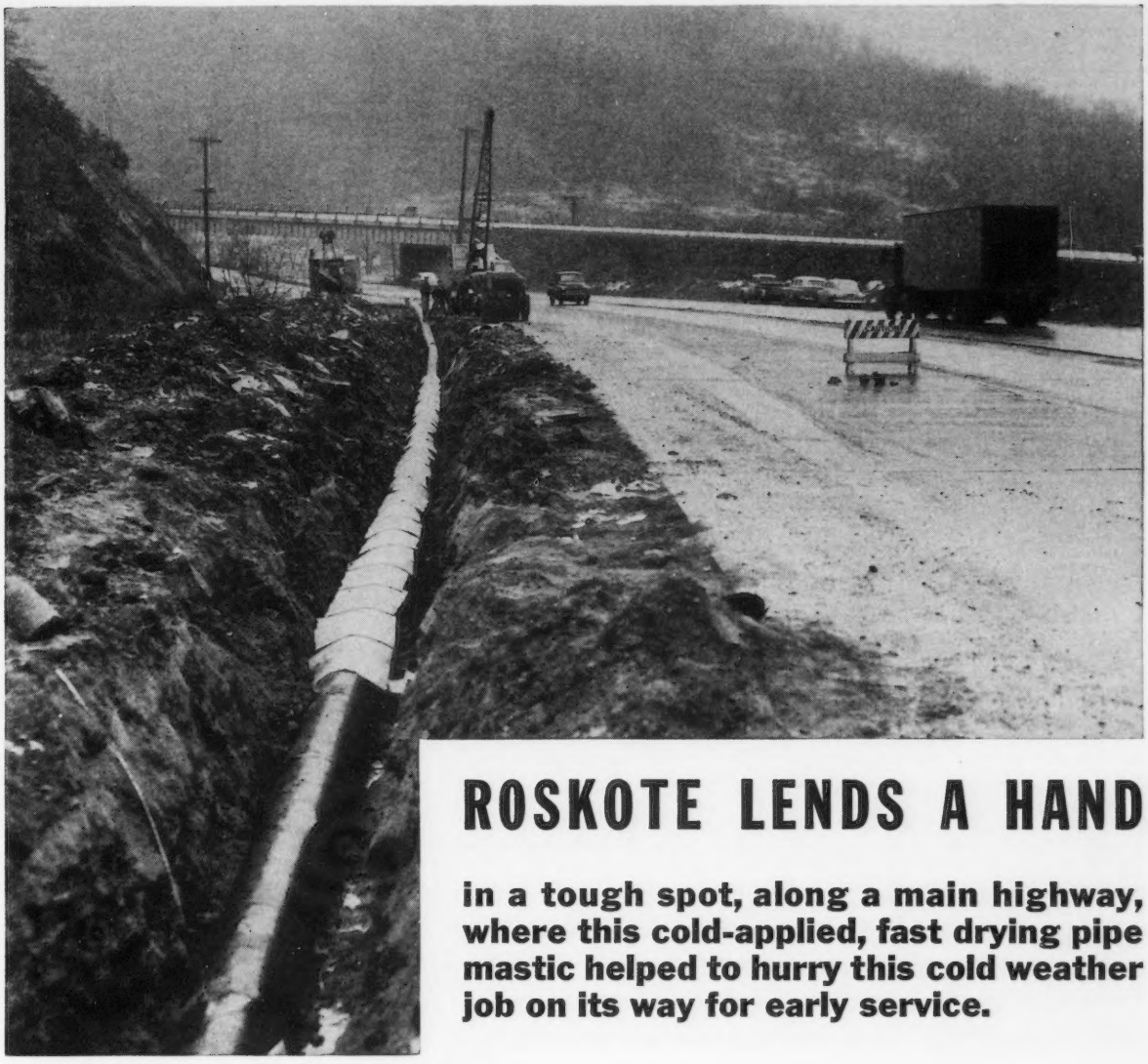

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(see chairman T-2H)

T-2H-2 Criteria for Reporting on and Evaluating Underground Coatings

(see chairman T-2H)

T-2H-3 Specifications

(see chairman T-2H)

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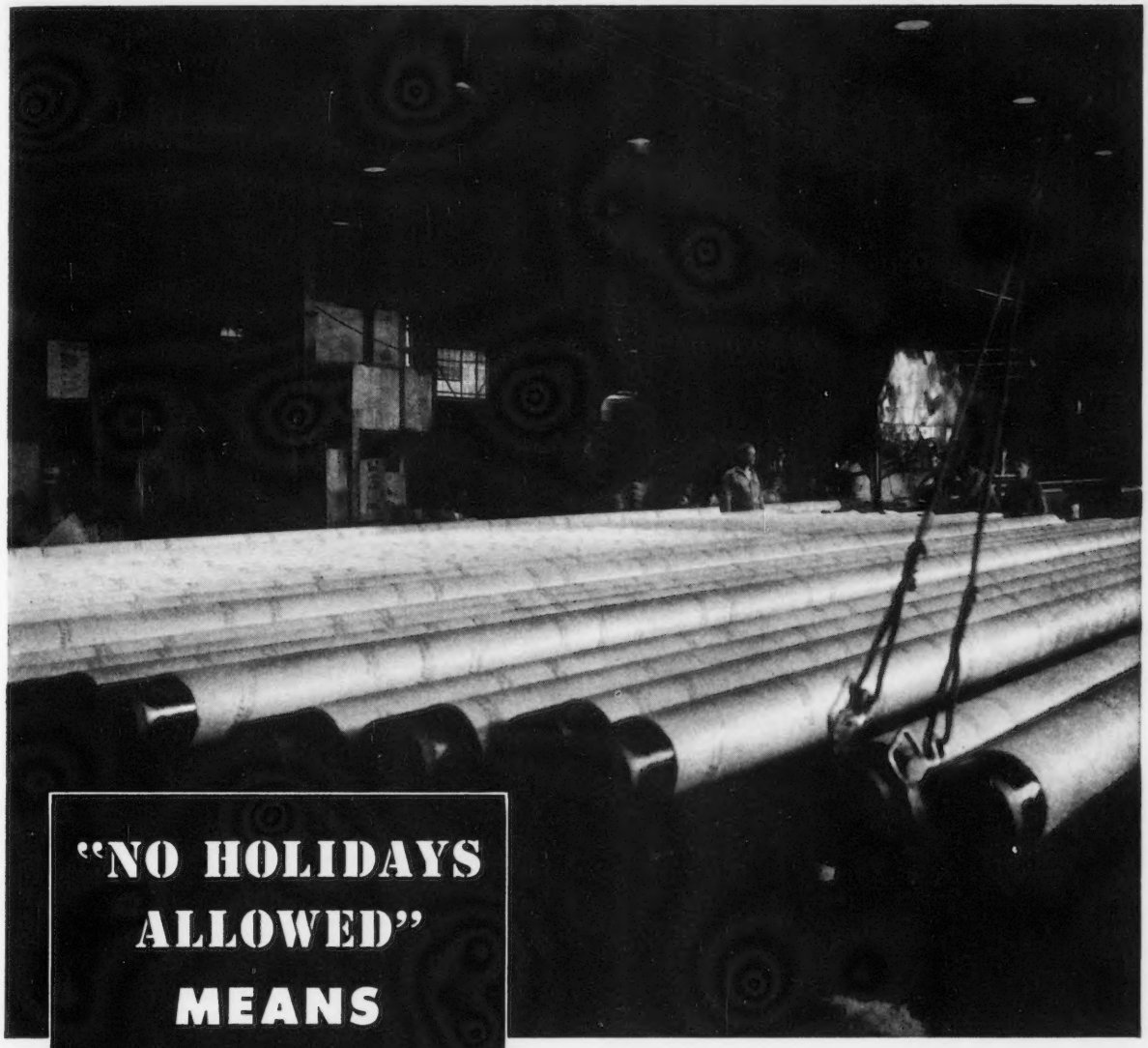

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J. J. Wise, Vice Chairman, Arkansas-Louisiana Gas Company, Box 1734, Shreveport, La.

T-2K-1 History and Results

H. D. Segool, Chairman, The Kendall Co., Polyken Sales Div., 309 West Jackson Blvd., Chicago, Ill.

T-2K-2 Physical Characteristics

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T-2K-3 Research and Development

A. C. Kilberg, Chairman, Minnesota Mining & Mfg. Co., 900 Fauquier Ave., St. Paul, Minnesota

T-2K-4—Application

R. B. Bender, Chairman, Plastic Engineering & Sales Co., Box 1037, Ft. Worth, Texas

T-2K-5 Standards

C. A. Bailey, Chairman, Johns-Manville Sales Corp., 22 East 40th St., New York, N. Y.

T-3 GENERAL

F. W. Fink, Chairman, Battelle Memorial Institute, 505 King Ave., Columbus, Ohio.
A. H. Roebuck, Vice Chairman, Production Research Division, Continental Oil Company, Ponca City, Oklahoma.

T-3A Corrosion Inhibitors

J. L. Wasco, Chairman, The Dow Chemical Co., Bldg. 438, Midland, Michigan.
S. K. Coburn, Vice Chairman, Association of American Railroads, 3140 S. Federal St., Chicago, Illinois.

• T-3A-1 General Theory of the Action of Corrosion Inhibitors

W. W. Sweet, Chairman; Research & Development Dept., Colgate Palmolive Co., 105 Hudson St. Jersey City, N. J.

• T-3A-2 Methods of Testing & Screening Corrosion Inhibitors

(Chairman to be Selected)

• T-3A-3 Materials Available for and Application of Corrosion Inhibitors

Lyle Timm, Chairman; Sharples Chemicals, Inc., Box 151, Wyandotte, Mich.

T-3B Corrosion Products

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T-3C Annual Losses Due to Corrosion

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T-3D Instruments for Measuring Corrosion

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• T-3D-1 Electrical Holiday Inspection of Coatings

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T-3E Railroads

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• T-3E-2 Corrosion in Railroad Hopper Cars

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T-3F Corrosion by High Purity Water

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J. F. Eckel, Vice Chairman; Dept. of Metallurgical Engineering, Virginia Polytechnic Institute, Blackburg, Va.

T-3F-1 Facilities for Production of High Purity Water

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T-3F-2 Inhibitors

R. C. Ulmer, Chairman, Combustion Engineering Co., 200 Madison Avenue, New York, N. Y.

T-3F-3 Corrosion Products

R. U. Blaser, Chairman, Babcock & Wilcox Co., Alliance, Ohio

T-3F-4 General Corrosion Problems

V. J. Payton, Chairman, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

T-3F-5 Declassification

J. L. English, Chairman, Oak Ridge National Lab., Box P, Oak Ridge Tenn.

T-3F-6 Intercommittee Activities

E. P. Partridge, Chairman, Hall Labs., Inc., Box 1346, Pittsburgh, Pa.

T-3F-7 Bibliography

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T-3G Cathodic Protection

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• T-3G-1 Cathodic Protection of Hull Bottoms of Ships

L. P. Sudrabin, Chairman, Electro Rust-Proofing Corp., Box 178, Newark, New Jersey.

• T-3G-2 Cathodic Protection of Heat Exchangers

R. B. Teel, Chairman, The International Nickel Co., Inc., Box 262, Wrightsville Beach, N. C.

• T-3G-3 Cathodic Protection of Process Equipment

A. A. Brouwer, Chairman, The Dow Chemical Co., Midland, Michigan.

T-3H Tanker Corrosion

W. S. Quimby, Chairman; Res. & Tech. Dept., The Texas Company, Box 509, Beacon, New York.

T-4 UTILITIES

Irwin C. Dietze, Chairman, Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles, Calif.

T-4A Effects of Electrical Grounding on Corrosion

T. R. Stilley, Chairman; Good-All Electric Mfg. Co., Good-All Bldg., Ogallala, Neb.

T-4A-1 Recommendations for Materials to Be Used for Electrical Grounding to Reduce Corrosion

(Appointment of chairman pending)

T-4A-2 Recommendations for Grounding on Private Premises

Irwin C. Dietze, Chairman, Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles, Calif.

T-4B Corrosion of Cable Sheaths

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D. T. Rosselle, Vice Chairman, Southern Bell Telephone & Telegraph Co., 1424 Hurt Building, Atlanta, Ga.

• T-4B-1 Lead and Other Metallic Sheaths

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• T-4B-2 Cathodic Protection

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• T-4B-3 Tests and Surveys

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• T-4B-6 Stray Current Electrolysis

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T-4D Corrosion by Deicing Salts

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W. H. Bruckner, Vice Chairman, University of Illinois, Urbana, Illinois.

T-4D-1 Procedures for Conducting Field Tests Below Ground

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T-4D-2 Co-ordination of Field Programs Between Cities and Transportation Companies

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T-4E Corrosion by Domestic Waters

T. E. Larson, Chairman, Illinois State Water Survey, Box 232, Urbana, Illinois.

T-4F Materials Selection for Corrosion Mitigation in the Utility Industry

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• T-4F-1 Materials Selection in the Water Industry

Daniel Cushing, Chairman, 148 State St., Boston, Massachusetts.

• T-4F-2 Materials Selection in the Electric Industry

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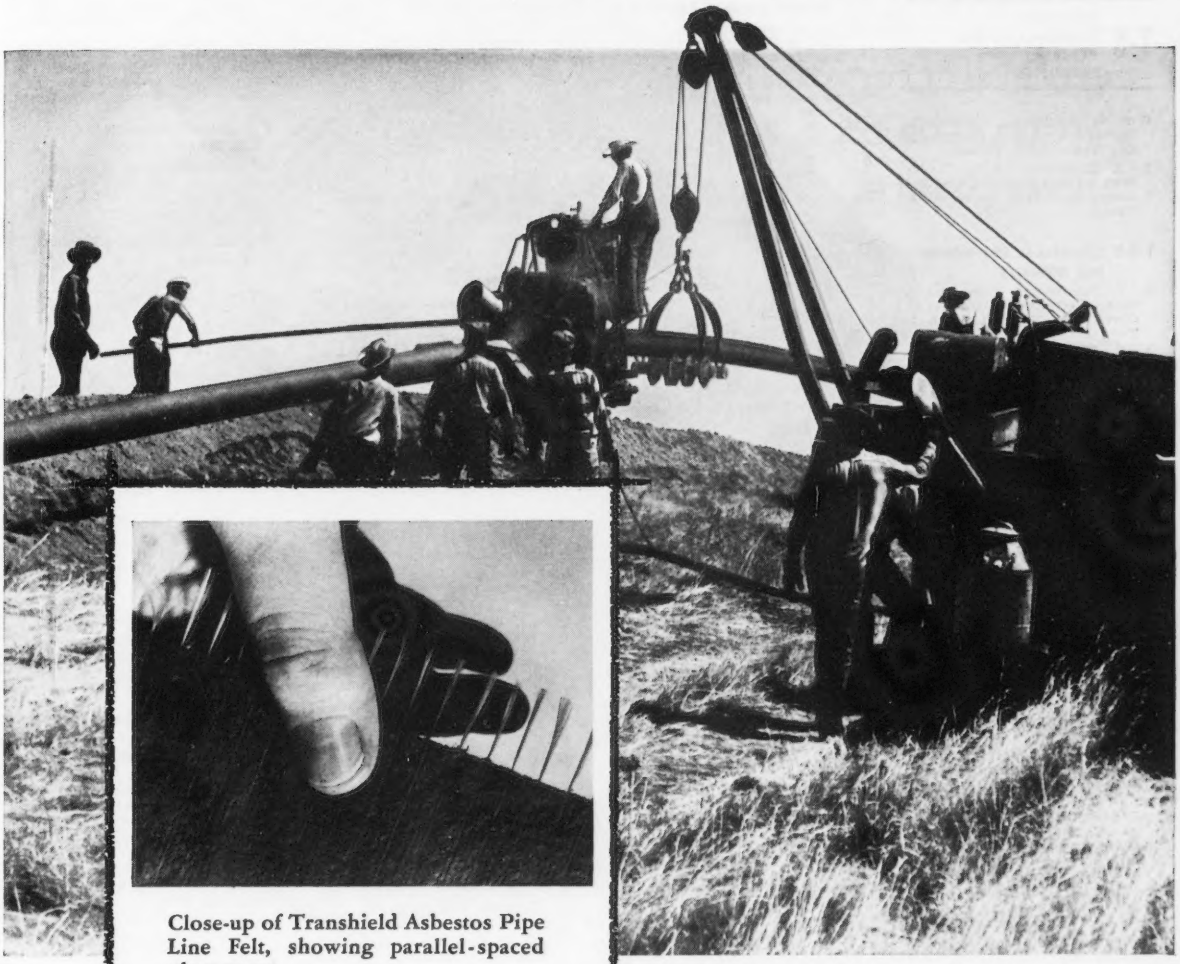

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T-5 Corrosion Problems in the Process Industries

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J. L. McPherson, Vice-Chairman; 427 Murdock Ave., R.F.D. 2, Library, Pa.

• T-5B-2 Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry

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• T-5B-3 Oil Ash Corrosion

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• T-5B-5 Corrosion by Molten Salts and Metals

W. D. Manly, Chairman, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

T-5C Corrosion by Cooling Waters

• T-5C-1 Corrosion by Cooling Waters (South Central Region)

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• T-5D-5 Water and Salt Solutions

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• T-5D-6 Organic Chemicals

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• T-5D-8 Methods and Criteria for Evaluating Plastics in Chemical Environment

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T-6 Protective Coatings

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• T-6A-3 Vinylidene Chloride Polymers

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• T-6A-4 Phenolics

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• T-6A-5 Polyethylene

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• T-6A-6 Rubber and Elastomers

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• T-6A-9 Furanes

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• T-6A-12 Fluorocarbons

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• T-6A-13 Chlorinated Rubbers

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• T-6A-14 Organic-Brick Covered

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• T-6A-15 Rigid Vinyls

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• T-6A-16 Bituminous

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• T-6A-17 Polyurethanes

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• T-6A-18 Hypalon

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T-6B Protective Coatings for Resistance to Atmospheric Corrosion

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T-6B-1 Linseed and Other Drying Oils

Joseph Bigos, Chairman, Applied Research Laboratory, United States Steel Corp., Monroeville, Penn.

T-6B-2 Ester Gum Oil

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T-6B-3 Straight Phenolic Oil Varnish

John W. Nee, Chairman, Briner Paint Mfg. Co., 3713 Agnes St., Corpus Christi, Texas

T-6B-4 Modified Phenolic Oil Varnish

John W. Nee, Chairman

T-6B-5 Straight Alkyd Varnish

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T-6B-6 Modified Alkyd Varnish

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T-6B-7 Epoxy Esters

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(Continued on Page 12)

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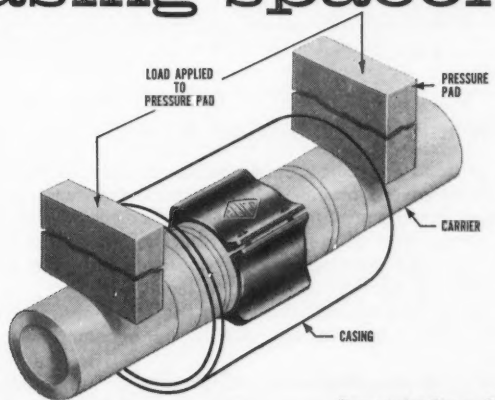

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T-6B-8 Epoxy (Amine Cured)

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T-6B-11 Metallic Silicates

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T-6B-12 Coal Tar

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T-6B-13 Asphalt

C. C. Allen, Chairman, Anderson-Pritchard Oil Co., 1000 Liberty Bank Bldg., Oklahoma City, Okla.

T-6B-14 New Developments

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T-6C Protective Coatings for Resistance to Marine Corrosion

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T-6D Industrial Maintenance Painting

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T-6D-1 Economics of Maintenance Painting

S. L. Lopata, Chairman, Carboline Co., 331 Thornton Ave., St. Louis, Mo.

T-6D-2 Standardization of Scope of Painting Specifications

L. L. Sline, Chairman, Sline Industrial Painters, 2162 Gulf Terminal Dr., Houston, Tex.

T-6D-3 Paint Programs

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T-6E Protective Coatings in Petroleum Production

F. T. Rice, Chairman, The Pure Oil Co., 35 E. Wacker Drive, Chicago, Ill.

D. F. Dial, Jr., Vice-Chairman; The Pure Oil Co., Box 239, Houston, Texas

T-6F Protective Coatings Equipment, Methods and Costs

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T-6G Surface Preparation for Organic Coatings

S. C. Frye, Chairman, Research Dept., Bethlehem Steel Co., Bethlehem, Pa.

T-6H Glass Linings and Vitreous Enamels

G. H. McIntyre, Chairman, Ferro-Enamel Corporation, 4150 East 56th Street, Cleveland, Ohio.

T-6J Protective Coating Application Problems

T-6J Los Angeles Area, Protective Coating Application Problems

Ivan Sullivan, Chairman, Spence & Sullivan, Inc., 344 East Carson St., Torrance, Cal.

F. M. McConnell, Vice Chairman, Service Coatings Corp., 217 North Lagoon, Wilmington, Cal.

W. M. Jakway, Secretary, Bechtel Corp., Box 58424, Los Angeles, Cal.

T-6J-1 Specification Writing

Newell Tune, Chairman, Dept. of Water & Power, 510 East Second St., Los Angeles, Calif.

T-6J-2 Application Procedure

J. E. Lacy, Chairman, Barrett Div., Allied Chem. & Dye Corp., 923 East 3rd St., Los Angeles, Calif.

T-6J-3 Inspection Techniques

Flora Lombardo, Chairman, Coatings & Fiberglass Res. Co., 5000 District Blvd., Los Angeles, Calif.

T-6J-4 Cost Evaluation

T. Doyle, Chairman, Furane Plastics, 4516 Brazil St., Los Angeles, Calif.

T-6K Corrosion Resistant Construction With Masonry and Allied Materials

L. R. Honnaker, Chairman; E. I. DuPont de Nemours Company, Inc., Eng. Dept., 13W15 Louviers Bldg., Wilmington, Del.

George P. Gabriel, Vice Chairman, Atlas Mineral Products Company, Mertztown, Pa.

T-6R Protective Coatings Research

Joseph Bigos, Chairman, Applied Research Lab., U. S. Steel Corp., Monroeville, Penn.

J. H. Cogshall, Vice-Chairman, Pennsylvania Salt Mfg. Co., 3 Penn. Center Plaza, Philadelphia, Pa.

T-7 Corrosion Coordinating Committee

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C. A. Erickson, Jr., Vice Chairman; The Peoples Natural Gas Company, Two Gateway Center, Pittsburgh 22, Pa.

T-7A Northeast Region Corrosion Coordinating Committee

C. A. Erickson, Jr., Chairman, The Peoples Natural Gas Company, 140 Stanwix Street, Pittsburgh, Pa.

L. Andrew Kellogg, Vice-Chairman; Niagara Mohawk Power Corp., 300 Erie Blvd., West, Syracuse, N. Y.

T-7A-1 Charleston Coordinating Committee on Corrosion

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K. R. Gosnell, Vice Chairman, Godfrey L. Cabot, Inc., Union Building, Charleston, West Va.

H. W. Hetzer, Secretary, West Virginia Water Service Co., Box 1090, Charleston, West Va.

T-7B North Central Region Corrosion Coordinating Committee

(Chairman to be elected)

J. O. Mandley, Vice Chairman, Michigan Consolidated Gas Co., 415 Clifford, Detroit, Mich.

T-7C Southeast Region Corrosion Coordinating Committee

Ernest W. Seay, Jr., Chairman, Chespeake & Potomac Tel. Co. of Va., 120 W. Bute St., Norfolk, Va.

T-7D South Central Region Corrosion Coordinating Committee

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C. L. Woody, Vice Chairman, United Gas Corporation, Box 2628, Houston, Texas

• ***T-7D-1 Houston Section Corrosion Coordinating Committee***

C. L. Mercer, Chairman, Southwestern Bell Telephone Co., Box 58, Westfield, Texas

T-7E Western Region Corrosion Coordinating Committee

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J. S. Dorsey, Vice Chairman, Southern California Gas Co., 3249 Terminal Annex, Los Angeles, Calif.

T-7F Canadian Region Corrosion Coordinating Committee

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R. E. Kuster, Vice Chairman, Union Gas Co. of Canada, Ltd., 48 Fifth Street, Chatham, Ontario, Canada

Nominations for the 1958 Whitney and Speller Awards

The Willis Rodney Whitney Award is given in recognition of public contributions to the science of corrosion. A contribution to science is defined as the development of new information or the development of a more satisfactory theory which contributes to a more fundamental understanding of corrosion phenomena.

The Frank Newman Speller Award is given in recognition of public contributions to corrosion engineering. A contribution to engineering is defined as the development or improvement of a method, apparatus or material by which the control of corrosion is facilitated or made less costly.

Nominations may be made by local sections or may be proposed directly to the Chairman of a Region by individual members up to June 1, 1957. In any case, nominations should be accompanied by an appropriate statement of the basis of the proposal.

Procedure in the Selection of Persons to Receive these awards was published beginning on Page 98 of the March, 1956 issue of Corrosion, or anyone interested may get a copy by writing to Central Office NACE, 1061 M & M Bldg., Houston 2, Texas.

(Left) NO-OX-ID and NO-OX-IDized Wrapper application by Traveliner. (Right) NO-OX-ID kettle.

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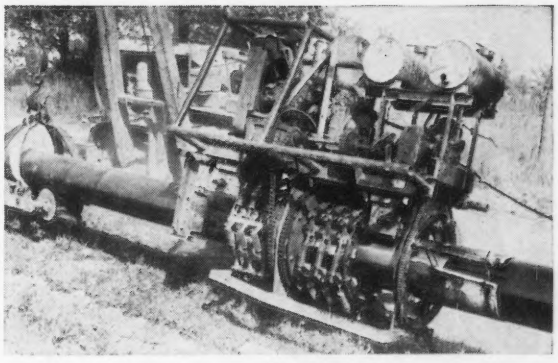

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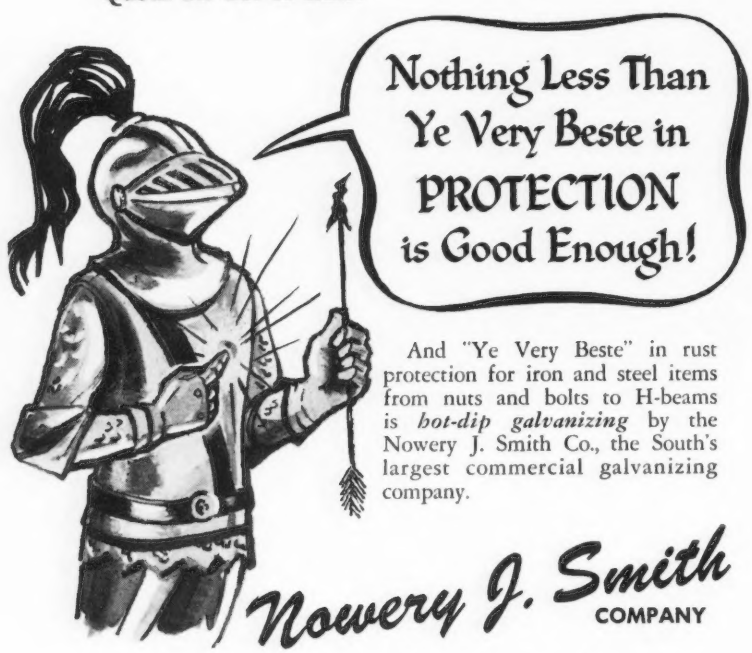

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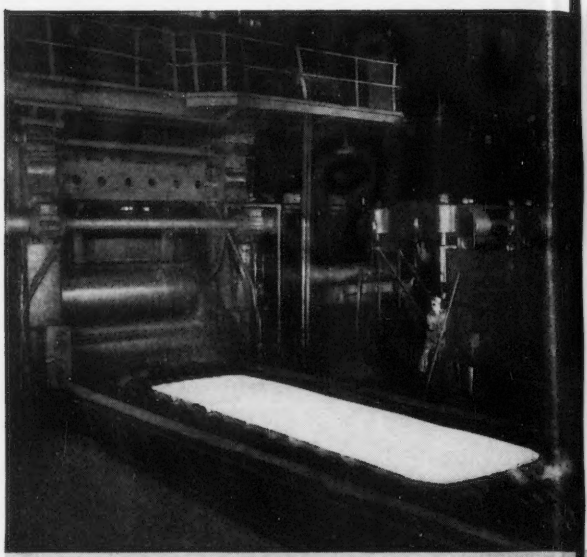

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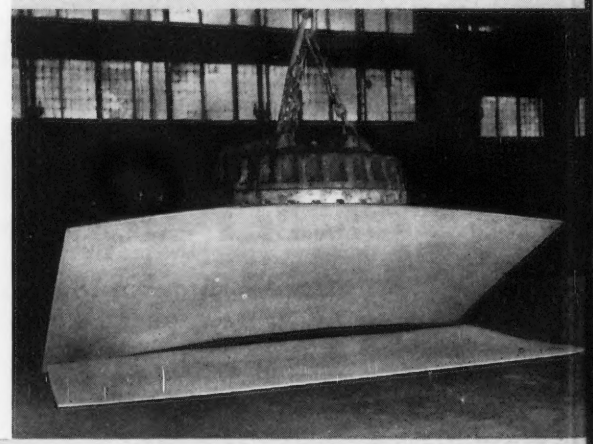

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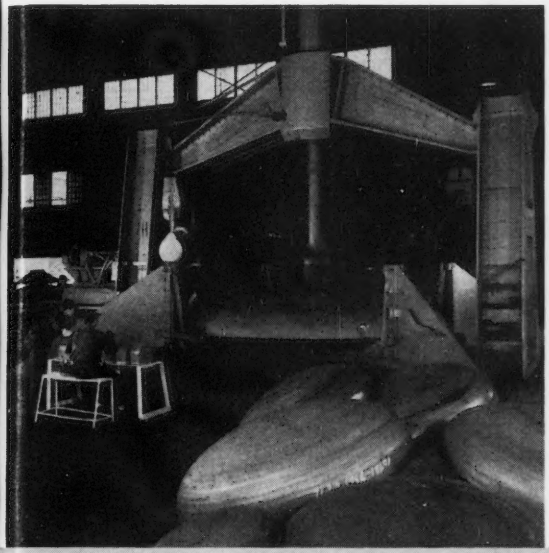

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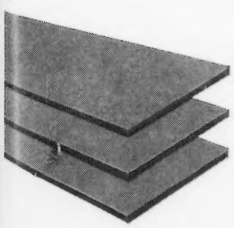

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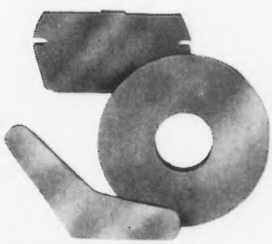

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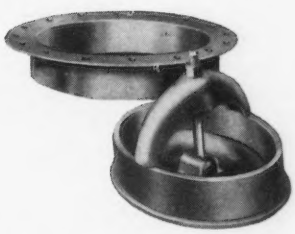

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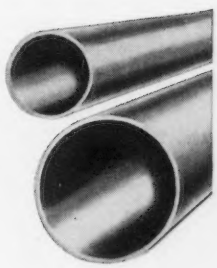

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 13 March, 1957 No. 3

Topic of the Month

Variability in Working Copper Sulfate Half Cells

By K. G. COMPTON*

THE WIDESPREAD use of the copper sulfate half cell as a reference electrode in corrosion measurements has resulted largely from the publication of a paper by Ewing[1] in 1939 in which he recorded observations on its temperature coefficient, polarization and resistance characteristics. He proposed this electrode as the most practical of several considered and pointed out that significant errors could be encountered under some conditions of use.

Pope[2] presented a paper at the 1955 NACE conference in Chicago showing the variations in the potential between two lead chloride half cells in contact with the earth. He showed that the potential differences varied with position, with time, and with whether the earth was moistened with tap water or a saline solution. It was found that the range of variation in these cells was approximately 35 millivolts.

In connection with previous work of a Task Group of NACE Technical Unit Committee T-4B, three sets of measurements were made with a view to exploring the reproducibility of measurements with working half cells. A group of 13 copper sulfate half cells similar in form to the most widely used commercial product, were used in this study. From time to time they were serviced (i.e., taken apart, cleaned, filled with fresh crystals and solution and reassembled.) Measurements were made over an 18 month period of the potential between these electrodes and a reference saturated calomel electrode at a temperature of 25 ± 1C in a dilute solution of copper-sulfate.

A second and third set of measurements were made at a location in an area free from stray current and the influence of buried structures. Two concentric circles were laid out with radii of 10 and 30 feet, as shown in Figure 1. Stakes were driven at the center and at the cardinal points of the compass on both circles. All measurements were made when the soil was naturally damp. Neither the difference in temperature nor the amount of light were significant factors in these measurements.

In the second experiment one half cell was placed at the center stake and each of nine others were placed in random order at each of the stakes on the circles. Measurements were made between the fixed electrode and the roving electrodes with a potentiometer voltmeter. It was noted that moving a given electrode from spot to spot in a small area produced variations in the potential reading.

The third experiment consisted in making measurements between the fixed electrode and one roving electrode placed at each of the stakes and at five positions within a one foot radius around each of the stakes, as shown by the dots at each station in Figure 1.

The data obtained from these three experiments are given in Table 1. It is apparent that differences in potential measurements between structures and half cells or between half cells below $\pm$ 10 mv (less than 3σ) have little significance. With other limitations in measurement perhaps twice this variation should be neglected. It is the experience of some engineers that surface gradient measurements have significance at lower potential differences than structure to half cell measurements, particularly in indicat-

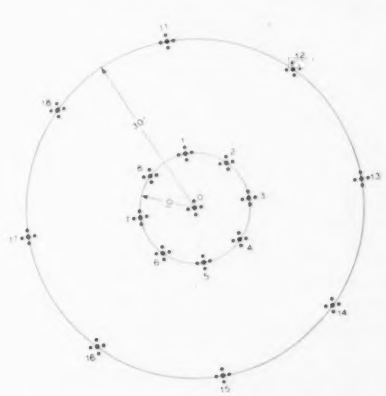

Figure 1—Pattern for checking reproducibility of half cell to half cell voltages with earth as the connecting bridge.

* Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

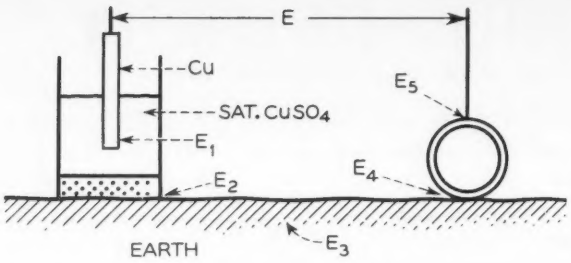

Figure 2—Components of a half cell to structure potential measurement.

TABLE 1—Variations in Potential Measurements With Various Half Cells

Experiment No.	No. of Observations	Average $\bar{X}$ in Millivolts	Standard Deviation σ in Millivolts	Coefficient of Variation v in %	Range in Millivolts
1	78	68.6	3.3	4.82	15
2	120	7.75	2.7	35.8	13.5
3	80	10.12	2.86	28.2	21

ing the direction of current flow in the earth. Similarly smaller differences are significant if the same measurements are made with cathodic protection current on and with it off.

Consider a measurement between a half cell and a cable or pipe, both of which are in contact with the earth as shown in Figure 2. The resultant potential E is composed of the algebraic sum of all the potentials in the circuit. The potential E_1 is the contact potential of the copper electrode to the saturated copper sulfate solution. While it is relatively constant and reproducible, it is subject to variations due to impurities in the copper sulfate solution, variations in the composition and state of the copper surface, films on the copper surface, variations in oxygen content of the solution, and variations in temperature and light falling upon the copper surface. The potential E_2 is the liquid junction potential between the copper sulfate solution and the soil electrolyte and will vary with the composition of the latter. E_4 is the contact potential of the structure to the electrolyte in the soil and is the potential being investigated. It is composed of a static or single electrode potential and polarization potential. E_3 is the vector sum of the potentials in the earth and includes liquid junction potentials, due to variations in concentration and species of ions in the soil as well as any RI drops that may exist. E_5 is a contact potential between dissimilar metals and cannot be measured by ordinary means.

When measurements (E_4) are made between a structure and a half cell, the potentials E_1, E_2 and E_3 are the variables which limit reproducibility and lead to uncertainty. When measuring between two half cells, one must add the variability of the components E_1 and E_2 of both half cells. The RI drop component of E_3 may be overshadowed by the variability of the junction potentials. In view of the above, the author places increasingly less credence in values for differences in potential observed or reported, as they drop below 25 millivolts. In field measurements when the values get as low as 5 millivolts, no significance is attached to them at all. As a criterion for determining when half cells need reconditioning, a value of 5 mv is commonly used for the permissible difference between a test half cell and a reference half cell. In order to keep the variables as few in number as practicable, the author is not suggesting any change in this viewpoint.

References

1. Scott Ewing. AGA Proceedings, 624, 1939.
2. R. Pope. Unpublished data.

Cathodic Protection of the Coated Steel Gas Main Distribution System in New Orleans*

By SIDNEY E. TROUARD

Abstract

A report is given of the practical considerations involved in the cathodic protection of the coated steel gas main distribution system in New Orleans. Topics discussed include topography and soils in New Orleans, types of gas mains used in system, use of coatings, use of galvanic anodes, experience with rectifiers and ground beds, use of insulated joints, importance of educational programs, and cost of cathodic protection. Data are given for a portion of one periodic rectifier survey and yearly tests on three galvanic anodes.

Results secured were good. It was found that successful operation of cathodic protection in New Orleans could be materially aided by observing the following procedure: (1) Secure reasonably good coating of the mains to be protected, (2) Maintain the systems to be protected electrically continuous, and free from electrical contact with other metallic subsurface structures, (3) Maintain the electrical potential of the systems to be protected at least —0.85 volt to a copper sulfate reference electrode placed in the earth, (4) Maintain continuous operation of the device furnishing the current for cathodic protection, (5) In general use many small (rather than a few very large) units for furnishing the cathodic protection currents. This minimizes problems of cathodic coordination. 5.2.3

SIDNEY E. TROUARD is the Corrosion Engineer of New Orleans Public Service Inc., New Orleans, La. He received an electrical engineering degree from the University of Dayton in 1928 and since that time has been engaged in stray current electrolysis, corrosion mitigation and cathodic protection work on the electric, gas and transit plants of New Orleans Public Service Inc. Mr. Trouard is a licensed professional engineer (Louisiana) and a member of NACE, American Gas Assocation, American Institute of Electrical Engineers, and the Louisiana Engineering Society. He is a member of several Technical Practices Subcommittees of NACE, and a member and past chairman for two years of the AGA Corrosion Committee.

Introduction

CATHODIC PROTECTION has been used successfully in New Orleans since 1928. Originally it was applied to the coated steel high pressure gas mains which had been installed in the city in that year, stray railway currents being used as the source of current. A rectifier was first used for gas main cathodic protection in New Orleans in February, 1930.

In this paper, discussion will be limited to the practical aspects of cathodic protection of the local coated steel gas mains. Theories of the corrosion process will not be discussed, it being assumed that the readers are sufficiently conversant with the fundamentals that a discussion of this topic will be unnecessary.

Topography and Soils in New Orleans

Figure 1 shows contour lines of elevation of the city in elevation Cairo Datum. These elevations were measured in 1917. There is evidence to support the belief that subsequent soil settlement has occurred. For instance, the elevation of those portions of the city originally shown at elevation 20 feet is now actually at elevation 16 feet, or roughly 4.5 feet below mean sea level.

In New Orleans it has been noted that there is a definite relationship between the corrosivity of the soil in various areas and the surface elevation, Cairo Datum, of the areas. It has been found that the lower the elevation, the more corrosive is the soil. It also has been found that there is a definite relationship between the serviceable life of cast iron gas mains and the elevation of the soil—the lower the elevation, the shorter the life; also, the lower the elevation, the higher the maintenance costs because of main breaks, trapping, water troubles, etc.

There are good reasons for these relationships. New Orleans lies between the Mississippi River and Lake Pontchartrain, which, being connected with the Gulf of Mexico, is brackish. Prior to the development of the city, when no artificial levees or sea walls existed, the low areas which were at approximate sea level were largely cypress swamps, subject to overflows from both the Mississippi River and Lake Pontchartrain. In the overflows from the lake the soils were contaminated by the brackish overflow waters. In the case of the river overflows, the heavier sand particles deposited by gravity near the river front, accounting for the non-corrosive soils in this area, and the lighter silts and colloids remained in suspension until deposited in the lower and more remote areas. The elevation of the city varies from about 36 feet Cairo Datum, near the river front to 20 feet Cairo Datum in the lower areas. Mean sea level is 20.4 feet Cairo Datum.

As a result of the action mentioned above, there are three main soil zones:

1. River sand, which is mild and generally non-corrosive in nature. Soil resistivity ranges from 1000 to 3000 ohm-cm.

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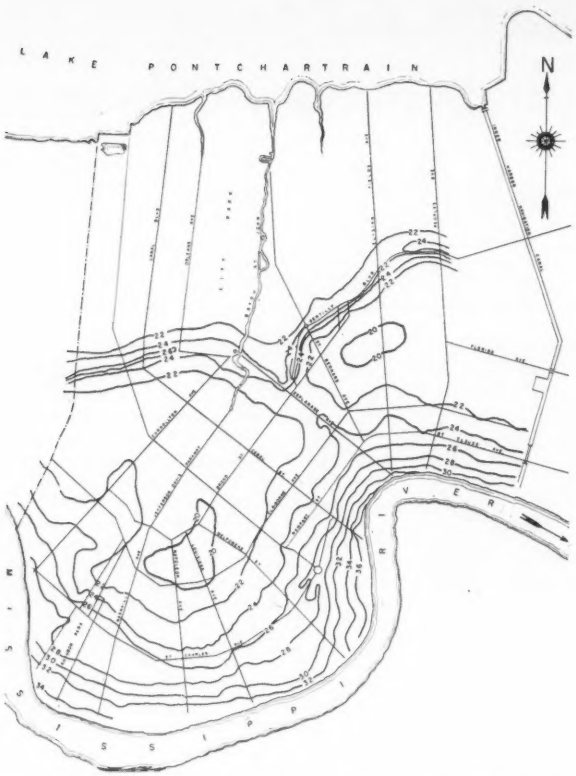

Figure 1—Map of New Orleans showing contour lines of elevation. Contours are expressed in feet and are referred to Cairo Datum. Mean Gulf level is 20.43 feet Cairo Datum.

2. Sharky Clay, which is high in colloid content, high in moisture, low in electrical resistance, approximately neutral or even slightly acid, high in salt content, and considered quite corrosive. Soil resistivity range is from 200 to 1000 ohm-cm.

3. Acid muck soil which is formed from decayed vegetation along the lake shore. This soil is high in total acid content, relatively high in electrical resistivity (1500 to 2500 ohm-cm), and extremely corrosive. It has been estimated that penetration would occur on an unprotected bare spot on a 6-inch steel main in this area in from four to five years. The presence of huge cypress stumps which remain at their original elevation while the mains subside with soil settlement, is one of the principal reasons for breakage of cast iron mains.

Most of the expansion of the gas systems in New Orleans is in the corrosive areas.

Gas Distribution System in New Orleans

As of December 1, 1955, the gas distribution system in New Orleans proper totaled 1057 miles of main. Of this total, 584 miles were of cast iron and 473 miles were of coated steel. Also included is approximately 0.5 mile of small diameter high pressure plastic main which was installed experimentally in 1955 for observation of performance and cost comparison. Service piping, almost exclusively steel, totaled 938 miles and ranged in size from ¾ inch to 20 inch. The number of gas services was 119,307, and the total number of meters was 162,414.

Coated steel gas mains range in size from 1 inch to 36 inch. The entire system of coated steel gas mains is cathodically protected.

Cast iron gas mains range in diameter from 2 inch to 30 inch. These mains are bare and are in intimate electrical contact with the bare cast iron city-owned water system. Because of the nature of the caulked joints, reasonable doubt exists as to the electrical continuity of the cast iron portion of the gas system. For this reason, and since the mains are bare and hence would require current of a large order of magnitude, cathodic protection of the cast iron system is considered impracticable.

Pressures range from approximately 125 psi on the high pressure steel system to nominally seven inches of water column on the utilization pressure system. Intermediate pressure mains normally operate at pressures ranging from 6 psi to 25 psi dependent upon load requirements.

Locally, there is a growing trend toward design of distribution systems in newer residential subdivisions wherein small diameter (1-inch, 2-inch, 3-inch) steel mains operating at so-called reduced high pressures (25-35 psi) are specified instead of the more conventional larger diameter (6-inch) main operating at utilization pressure. Despite the cost of a district pressure reducer station and individual residential regulators, this design patently offers important economic advantages in systems where the service concentrations are not too great. When it is considered that these newer systems are almost invariably installed in those sections of the city where soil conditions are most corrosive, and since the wall thickness of the mains and services are minimized (wall thickness of 1 inch steel main is 0.133-inch, wall thickness of a 6-inch main is 0.219-inch), it should be obvious that a high degree of perfection in design and operation of the cathodic protection system is required to ensure against corrosion failure.

Service Piping

The high pressure services are mill wrapped according to the same specifications as are the steel mains. Since high pressure services are tied to the mains electrically, they also receive cathodic protection. Present standard size for residential high pressure gas services is ¾ inch. Industrial and commercial high pressure services are usually larger, and are sized according to individual load requirements.

Utilization pressure services, predominantly 1½ inch black steel, are not bituminous coated, nor are they cathodically protected. A precast concentric jacket of a 1-3 mix of Portland cement and coarse sand has been found effective. Screwed joints are similarly cemented in the field. The service riser is

also cement-encased to a height 6 inches above the ground line, the application being made in the field with the aid of a prefabricated cardboard cylinder used as a concentric form. The cost is substantially the same as the cost of bituminous coating.

The practice of encasing gas services in cement has been in use in New Orleans for over fifty years and excellent results have been secured. This probably is because of the passivity effect of steel in the alkaline environment of the cement. In a system containing approximately 100,000 cement coated gas services, less than a dozen per year fail because of corrosion. The few failures occur where the cement coating has been knocked off and not replaced. No cases are known where corrosion occurred under sound, undamaged cement.

On a number of ¾-inch high pressure service risers it was found that the wrapping had been damaged above the ground line, usually by gardening activities. In several places water was found pocketed between the pipe and the wrapping in the vertical portions of the risers. Examination revealed very severe pitting in the overground zone which could not be cathodically protected. To guard against recurrence of this type of corrosion, construction standards were revised so that future service installations would be cemented from the underground service bend to the overground stop cock. The cement mortar being used is a 1:3 mix, poured in the field, with a prefabricated cylindrical cardboard tube used as a form. This standard is shown on Figure 2.

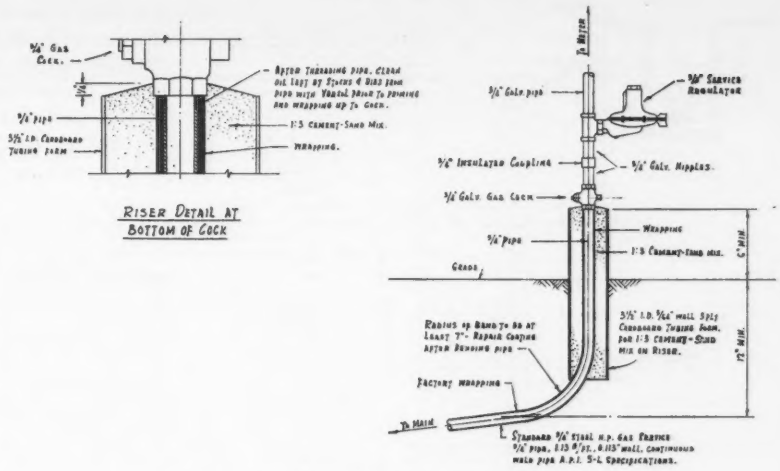

Figure 2—Standard for ¾-inch high pressure gas service riser.

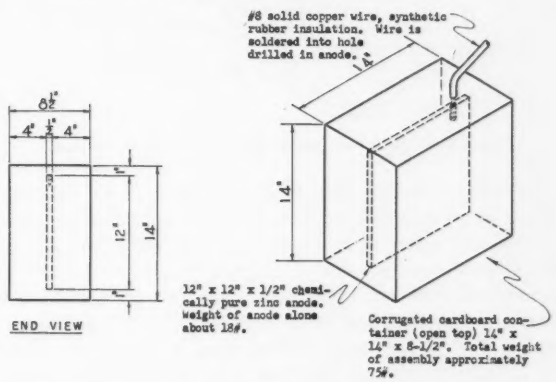
#8 solid copper wire, synthetic rubber insulation. Wire is soldered into hole drilled in anode.
8½"
4"
4"
12"
14"
END VIEW
14"
12" x 12" x 1/2" chemically pure zinc anode. Weight of anode alone about 18#.
Corrugated cardboard container (open top) 14" x 14" x 8-1/2". Total weight of assembly approximately 75#.

Figure 3—Zinc anode precast in artificial backfill. Zinc anode is centered in moist, homogeneous mixture of 50 percent gypsum, 50 percent bentonitic clay. Anode assembly is coordinated with expected construction work such that only enough anodes are precast to last one week. Anodes are then stored in damp atmosphere until used.

Coatings

The subject of pipe coatings is far too broad in scope to be treated fully here. The requisites of a good coating may be stated to be:

1. High electrical resistance, low moisture absorption; electrical resistance should not materially deteriorate with age.
2. Mechanical strength; ability to withstand rough field usage without excessive patching; ability to withstand damage when subjected to shifting soils (soil distortion) or unfavorable backfill; good bonding qualities.
3. Chemical stability; all component parts of the coating should be capable of withstanding attacks of chemicals, bacteria, etc. of soils.
4. Ability to withstand distortion, cracking, or disbonding in storage when subjected to temperature ranges encountered at point of storage.
5. Longevity of service.
6. Economic feasibility.

Gas mains presently being laid in New Orleans are all steel, and are mill wrapped according to the following general specifications:

1. Thorough cleaning, either by power driven rotary brushes, or preferably, by grit or shot blasting.
2. One coat of coal tar pipe line primer.
3. Double application of coal tar pipe line enamel, each application 1/32-inch minimum thickness.
4. Spiral wrap of reinforced glass fiber, 15 mil thickness.
5. Single application of coal tar pipe line enamel—1/32-inch minimum thickness.
6. Spiral wrapping of 15 pounds per square coal tar saturated asbestos felt.
7. Spiral wrap of Kraft paper.

Each succeeding application (except the Kraft paper) must be integrally bonded to the layer beneath it, and free of holidays. Minimum acceptable thickness of bituminous coating is 0.156-inch.

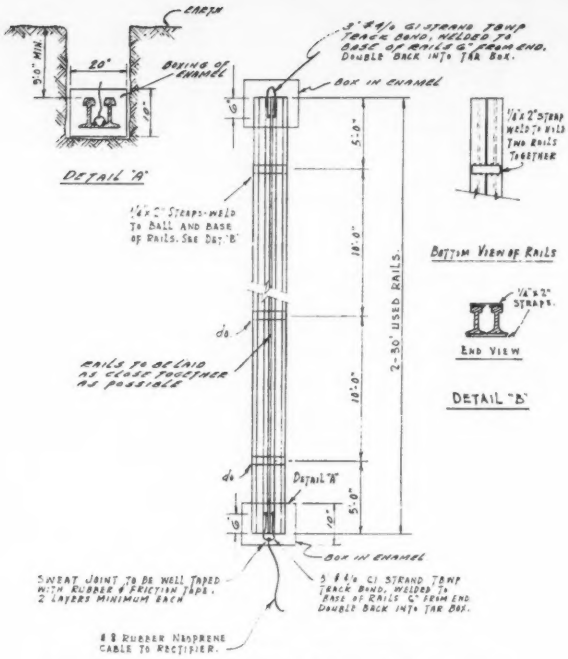

Figure 4—Typical rail ground bed for cathodic protection.

Locally it is felt that the coating system outlined above is economically feasible. If, in a distribution system, it were practicable to coat over the ditch, possibly a less expensive coating would be in order. However, mill wrapped pipe must be hauled to the warehouse, unloaded from gondolas, and stacked for future use. When needed, the pipe must be reloaded on trucks, hauled to the job site, unloaded in piles, later strung out for joint welding, etc. This large amount of handling makes it very desirable to use glass and felt wrappers in order to minimize patching. Then, again, in city distribution work, since a good neighbor policy should be followed, cathodic protection current requirements should be low. It does not necessarily follow that a pipe coating of practically infinite electrical resistance must be secured, but somewhere in between no coating and infinite resistance coating there lies a pipe coating of reasonable cost and of sufficiently high electrical resistance to permit cathodic protection with a high degree of safety.

New Orleans Public Service Inc. is a combination company serving the transit and the electric requirements of the community, as well as the gas needs. Since power costs for cathodic protection are small, the company does not attempt to balance such costs against coating costs. It prefers to secure a good quality coating so as to demonstrate beyond any doubt that it is following the good neighbor policy. The recognition and adoption of this good neighbor policy has proven sound, because in more than a quarter of a century of cathodic protection on the coated steel gas system, no complaints have been received.

The importance of pinholes and flaws in coating which are not discernible to careful visual inspection is perhaps being overemphasized in the industry. The role of cathodic protection is to supplement the coating. With adequate and carefully supervised cathodic protection, corrosion does not occur at pinholes. Careful patching of obvious bare spots, skid marks, and damaged coating and attention to good coating at field joints and service connections are of far more importance.

Galvanic Anodes

The gas system in New Orleans is expanding rapidly, particularly for residential use. Many of these extensions are relatively short (1000 feet or less) and are of new coated steel pipe extended from existing cast iron utilization pressure mains. Since these extensions are usually isolated pieces of steel, not tied together electrically, galvanic anodes rather than rectifiers are used for cathodic protection because of economies of original installation and maintenance. Over a period of years, these isolated pieces usually become integrated into a network of coated steel, at which time it may become more advantageous to install a small rectifier. In such cases the galvanic anodes are left tied to the system as insurance in case of rectifier outages. In general, rectifiers are used only on large networks of steel mains where current requirements are somewhat higher, and economies can be realized in original installations and subsequent maintenance and testing.

Since the steel gas mains are double wrapped and are generally high in electrical resistance to earth, zinc may be used to advantage as the galvanic anode material. Open circuit potential of a zinc anode to a $CuSO_4$ reference electrode placed in nearby earth is generally in the order of −1.10 volts. When tied to a reasonably well coated line (i.e., 50,000 ohm-feet coating resistivity), the system generally is brought to a safely negative potential (−0.90 volt to −1.00 volt) but not to an excessively negative potential, as would be the case if an anode material of higher driving voltage were utilized.

In order to prevent anodes from becoming high in electrical resistance to earth or decreasing in driving voltage due to the formation of films or scales, the anodes are backfilled in a mixture of gypsum and bentonitic clay. The sulfate ion in the gypsum acts as an effective film destroyer, and the practice of using the artificial backfill mix mentioned above has resulted in generally superior anode performance. In Figure 3 is shown the method used in New Orleans for precasting zinc anodes in a wet artificial backfill mix of 50 percent gypsum and 50 percent bentonitic clay. Anodes are precast only once a week, and then only enough are precast that all will be used within a week; meanwhile they are stored in a damp atmosphere. Anodes and artificial backfill are packaged in a corrugated cardboard box 14 inches x 14 inches x 8½ inches. The anodes themselves are flat zinc plates 12 inches x 12 inches x ½ inch, weighing roughly 18 pounds, and are made of commercially pure (99.92 percent) zinc, with impurities not exceeding the following:

Lead	0.08 percent
Iron	0.008 percent
Cadmium	0.003 percent

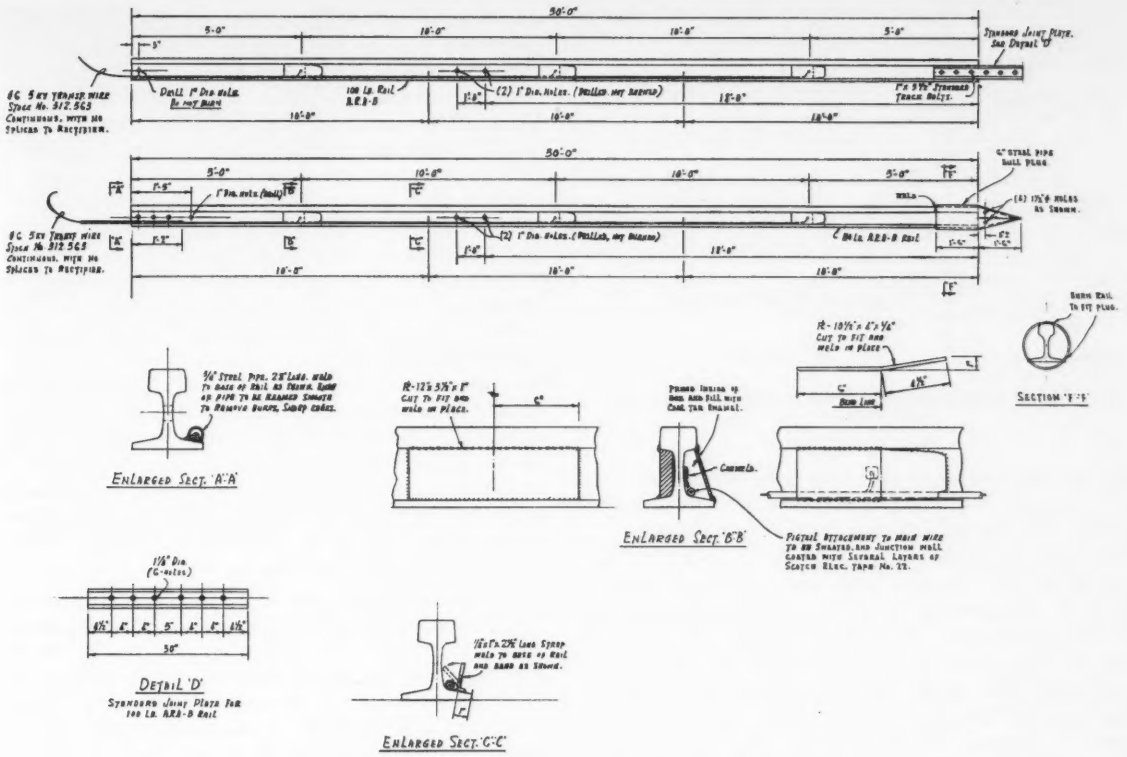

Figure 5—Construction details for standard deep vertical rail ground bed.

The anodes are buried below the ground water level, and a wire soldered into the anode is brought into a small handhole at sidewalk level, and there tied by means of a solderless connector to a similar wire attached to the main. In this way periodic electrical checks may be made of the performance of the anode and of the gas main being protected.

Magnesium anodes are used to a relatively limited extent for certain applications wherein larger amounts of current are desired. These anodes have performed with great satisfaction for a number of years. They too are artificially backfilled in a mixture of gypsum and bentonite. Open circuit potential of a standard magnesium alloy anode is in the order of —1.55 volts to a reference copper sulfate electrode. Newly developed magnesium alloy anodes are being used successfully in applications requiring still heavier currents. Open circuit potential of the new anode is —1.80 volts to a reference electrode. In installations where fairly heavy currents (0.1 ampere or more) are required, magnesium appears to be the logical choice, the electro-chemical equivalent of magnesium being superior to that of zinc. In very well coated lines where only small currents are needed to produce satisfactory potentials, zinc has been found to be well suited.

Soils in New Orleans are generally low in electrical resistance and high in moisture content. They are ideally suited for the satisfactory performance of galvanic anodes.

Approximately 1200 galvanic anodes are used on the gas system, more than 1000 of which are zinc.

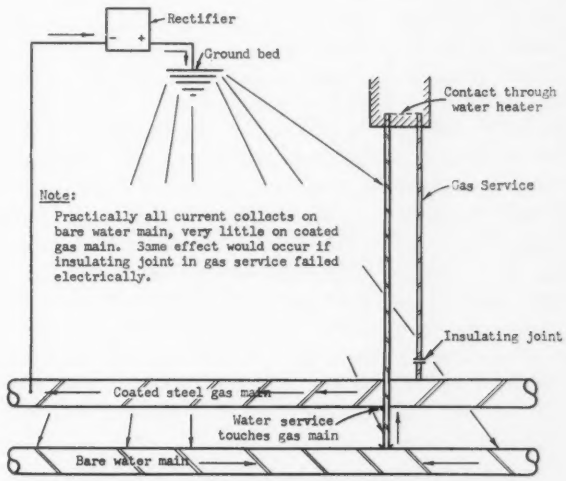
Rectifier
Ground bed
Contact through water heater
Gas Service
Note:
Practically all current collects on bare water main, very little on coated gas main. Same effect would occur if insulating joint in gas service failed electrically.
Insulating joint
Coated steel gas main
Water service touches gas main
Bare water main

Figure 6—Effects of accidential contact between underground mains.

Rectifiers and Ground Beds

A total of 40 rectifiers are used on the coated steel gas system. The older units are of the copper oxide type, the newer units of the selenium type. Several bulb type rectifiers are in operation, wherein the ground bed used is the live street car rail system. The latter forms an excellent ground bed, being very low in electrical resistance to earth and having the characteristics of evenly distributing the current into the earth. A rectifier with a relatively high voltage output is required to buck the rail to earth potentials.

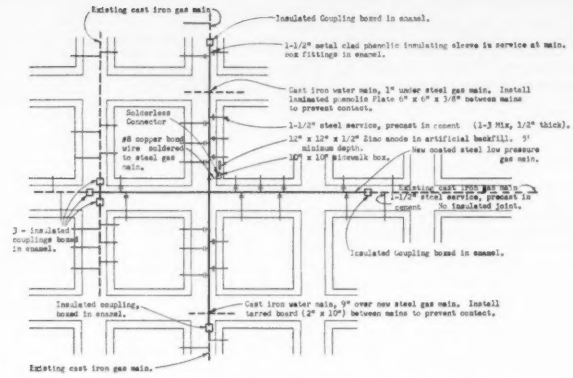
Existing cast iron gas main.
Insulated Coupling boxed in enamel.
1-1/2" metal clad phenolic insulating sleeve in service at main, cox fittings in enamel.
Cast iron water main, 1" under steel gas main. Install laminated phenolic Plate 6" x 6" x 1/8" between mains to prevent contact.
Solderless Connector
1-1/2" steel service, precast in cement (1-3 Mix, 1/2" thick).
#8 copper bond wire soldered to steel gas main.
12" x 12" x 1/2" Zinc anode in artificial backfill. 5' minimum depth.
12" x 10" pitcrete box.
New coated steel low pressure gas main.
Existing cast iron gas main.
1-1/2" steel service, precast in cement
No insulated joint.
3 - insulated couplings boxed in enamel.
Insulated Coupling boxed in enamel.
Insulated coupling, boxed in enamel.
Cast iron water main, 9" over new steel gas main. Install tarred board (2" x 10") between mains to prevent contact.
Existing cast iron gas main.

Figure 7—Typical cathodic protection layout on new coated steel gas main extension.

Also, current reversals must be zero in case of rectifier outages. Bulb type rectifiers are inexpensive and are well suited for this special application.

In general, rectifier currents are limited to three amperes or less. Ground beds normally used consist of two 30 foot parallel lengths of used street car tee rail, 100 pounds per yard. They are buried nine feet deep in a location at least 150 feet removed from water mains, cable sheaths, and other underground structures not intended to be included in the cathodic protection setup. Standards for the conventional horizontal ground bed are shown in Figure 4.

Occasionally it is necessary to install a rectifier in an area crowded with foreign structures such that no readily available open spot can be located for the ground bed. For such cases a special and rather unique ground bed design has been developed. A hole nominally 8 inches in diameter is drilled into the earth 250 feet to 300 feet in depth, and two 30-foot lengths of rail connected by a joint plate are lowered into the hole so as to form a 60-foot length of rail weighing roughly one ton. In drilling to this depth, the so-called Pleistocene clay layer is reached. Soil from this layer is very low in electrical resistance. Usually the hole can be drilled and the rails lowered in one day. The next day the hole will close in of its own accord, no special backfilling being necessary except for the top three or four feet. Details of this special deep vertical ground bed are shown in Figure 5.

The deep rail ground bed is more expensive than the conventional shallow horizontal ground bed, but in certain locations is economically feasible and readily solves the problem of where to install the ground bed when crowded conditions are encountered. One saving lies in the elimination of expensive trial ground bed installations and the attendant costs of coordinative tests with other utilities.

Insulated Joints

Insulated joints are indispensible in the effective application of cathodic protection. They are necessary to electrically isolate the coated steel gas main to be protected from other underground mains, and are of convenience in sectionalizing the cathodically protected system for facility in locating accidental contacts which may develop. The harmful effects of such accidental contacts are shown in Figure 6. Under this condition the cathodic protection of the coated steel gas main is rendered useless because practically all of the current will collect on the bare main, which has very low electrical resistance to ground, and very little will collect through the scars and holidays in the coating on the main which is to be protected. This results in the potential of the protected main being adversely affected from say −0.9 volts, to the potential of the bare main which may be −0.500 volts, and corrosion will result despite the rectifier. In installing new mains, such contacts should be avoided by using suitable physical separators, such as canvas base phenolic blocks or laminated glass plates between the coated main and crossing mains. In existing systems, such contacts must be located by electrical testing and removed as soon as practicable in order that effective cathodic protection can be restored.

In the utilization pressure system, cement encased services are insulated from the coated steel main by means of metal clad phenolic sleeves. In the high pressure services, the insulated joint is located in the riser above the ground line. Proprietary insulated couplings are used to insulate the steel mains at tie-in points to the cast iron gas system. Occasionally, insulated flanges are used in the high pressure system, or the flanges of valves may be insulated. In insulated flanges, it has been found advantageous to use full faced phenolic gaskets, and to resort to the use of relatively thick laminated phenolic thimbles ($\frac{7}{64}$ inch) over the bolts, rather than the conventional $\frac{1}{16}$ inch thickness thimble. Severe soil settlement and the prevalence of a high water table prompted the decision to adopt these standards.

In the proprietary insulated couplings used to insulate steel mains from cast iron mains, insulating polyethylene skirts, and insulating rubber gaskets are used on both the steel and the cast iron side of the joint. Despite this double precaution considerable trouble has been experienced in that frequently the insulated coupling fails electrically, short circuiting, or partially short circuiting the steel to the cast iron. Undoubtedly, the soil settlement condition encountered locally is an important factor in the occurrence of these expensive failures. Failures seem to occur most frequently because of the follower ring pinching through the rubber insulation. An attempt is being made to design an insulated joint which will operate satisfactorily despite the seemingly inevitable soil subsidence.

Typical practices employed on a new utilization pressure coated steel gas main extension are shown in Figure 7.

Corrosion Testing—Instruments—Records

It has been found helpful to check rectifier current output and potentials to a copper sulfate reference electrode at salient points on the system at least

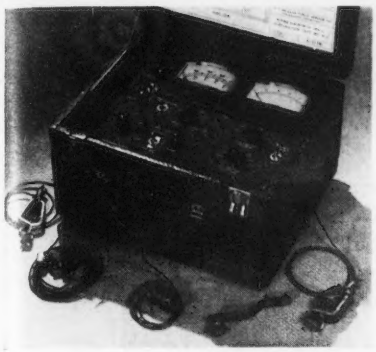

Figure 8—Galvanic anode testing assembly. Leads shown extending from side of case are 150 feet long and are attached to reels mounted in rear of assembly. Lead on left is connected to binding post No. 2 inside case and is attached to water hydrant. Lead on right is connected to binding post No. 4 inside case and is connected to copper sulfate electrode in remote earth.

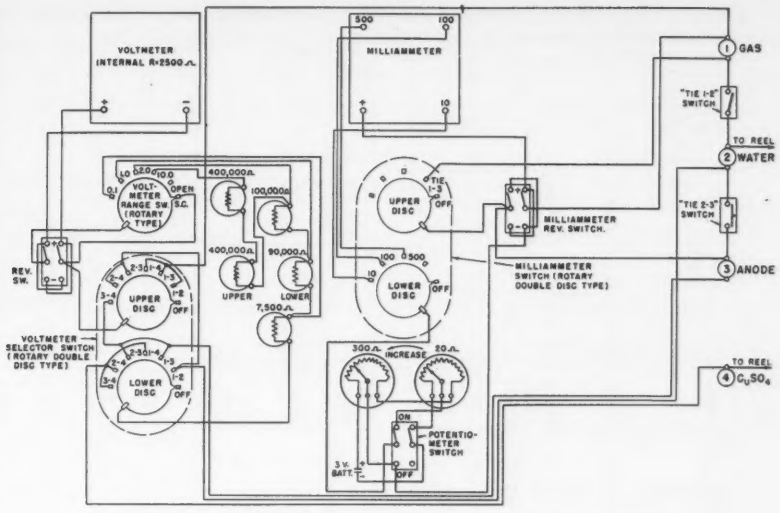

Figure 9—Wiring diagram of small electrolysis test set No. 2.

TABLE 1—Periodic Rectifier Survey

LOCATION	Type of Test	Previous Reading	PRESENT READING Maximum	Minimum	Average	Time	Date	Remarks
Tennessee and Florida	Gas main to $CuSO_4$	— .978v	— .760v	— .760v	— .760v	11:10 am	8/5/55	←
France and Florida, riverside	Gas main to $CuSO_4$	—1.250v	— .700v	— .700v	— .700v	10:00 am	8/8/55	← Contact
France and Florida, lakeside	Gas main to $CuSO_4$	—0.920v	— .910v	— .890v	— .900v	10:01 am	8/8/55	on
Mazant between Dorgenois and Law	Gas main to $CuSO_4$	—1.270v	— .700v	— .700v	— .700v	3:45 pm	8/4/55	← System
Mazant and Rocheblave	Gas main to $CuSO_4$	— .955v	— .970v	— .960v	— .965v	4:00 pm	8/4/55	
North Prieur and Gallier	Gas main to $CuSO_4$	— .985v	—1.020v	—1.010v	—1.015v	4:20 pm	8/4/55	
Bunny Friend Rectifier	Rectifier current	0.4 amp	0.5 amp	0.5 amp	0.5 amp	11:30 am	8/5/55	
France Rd. and L & N RR Tracks	Gas main to $CuSO_4$	—0.875v	—0.870v	—0.870v	—0.870v	12:01 pm	8/5/55	
France Rd. near Lake Pontchartrain	Gas main to $CuSO_4$	.....	— .900v	— .880v	— .890v	1:00 pm	8/5/55	
Downman Road Rectifier	Rectifier current	1.1 amp	1.25 amp	1.25 amp	1.25 amp	1:20 pm	8/5/55	
Station 3, Chef Hwy., riverside	Gas main to $CuSO_4$	—1.030v	—1.100v	—1.100v	—1.100v	1:30 pm	8/5/55	
Gentilly Oaks Subdivision	Gas main to $CuSO_4$	—1.050v	—1.170v	—1.170v	—1.170v	1:55 pm	8/5/55	
Paris Road near Intracoastal Canal	Gas main to $CuSO_4$	—1.100v	—1.110v	—1.110v	—1.110v	2:15 pm	8/5/55	
Paris Road and Bayou Bienvenue	Gas main to $CuSO_4$	—1.030v	—1.050v	—1.050v	—1.050v	2:45 pm	8/5/55	
Chrysler Tank Engine Plant	Gas main to $CuSO_4$	—1.010v	—1.090v	—1.090v	—1.090v	3:15 pm	8/5/55	
Chef Hwy. and Wilson Road	Rectifier current	2.15 amp	2.30 amp	2.30 amp	2.30amp	3:40 pm	8/5/55	
Tulip between Dwyer and Prentiss	Gas main to $CuSO_4$	— .975v	—1.050v	—1.050v	—1.050v	3:45 pm	8/5/55	
Majestic Oaks Dr. and Dwyer	Gas main to $CuSO_4$	— .980v	—1.020v	—1.020v	—1.020v	4:30 pm	8/5/55	
Dorothea and Dorian	Gas main to $CuSO_4$	— .900v	— .720v	— .720v	— .720v	11:50 am	8/8/55	← Contact
Hayne Blvd. and Lamb Road	Rectifier current	0.7 amp	0.9 amp	0.9 amp	0.9 amp	10:50 am	8/8/55	← on
Hayne Blvd. and Pompano	Gas main to $CuSO_4$	— .945v	— .790v	— .790v	— .790v	11:00 am	8/8/55	← System

Note: Weather was warm and cloudy.

every three months. A form sheet used to record such data is shown in Table 1.

It also has been found advantageous to make an annual check of the electrical continuity of the various steel gas systems under protection. This survey quickly reveals broken bonds, or bonds inadvertently left open, which would leave a portion of the system without protection.

A periodic annual check is made of all galvanic anodes, and the results are recorded as shown on the form sheets (see Tables 2, 3 and 4). From these readings a running check may be kept of such useful performance data as anode current output, anode resistance to earth, coating resistance, potential of the main to a copper sulfate electrode, and open circuit potential of the anode to the same electrode. A meter assembly, designed and built locally, and especially devised for the testing of galvanic anodes is shown physically in Figure 8, and diagramatically in Figure 9. In use, wires from the four respective binding posts are extended to:

1. Gas main
2. Water hydrant
3. Galvanic anode
4. $CuSO_4$ electrode, at least 100 feet removed from anode.

By proper manipulation of the rotary selector switch, all possible combinations of readings may be secured between the four binding posts, with anode current on and off. A convenient feature consists of two 150 foot reels of wire and a winding crank incorporated in the assembly to facilitate testing. The voltmeter is of 100,000 ohms per volt sensitivity, with ranges of 0.1, 1.0, 2.0, and 10.0 volts. The milliammeter ranges are 0.01, 0.1, and 0.5 amps.

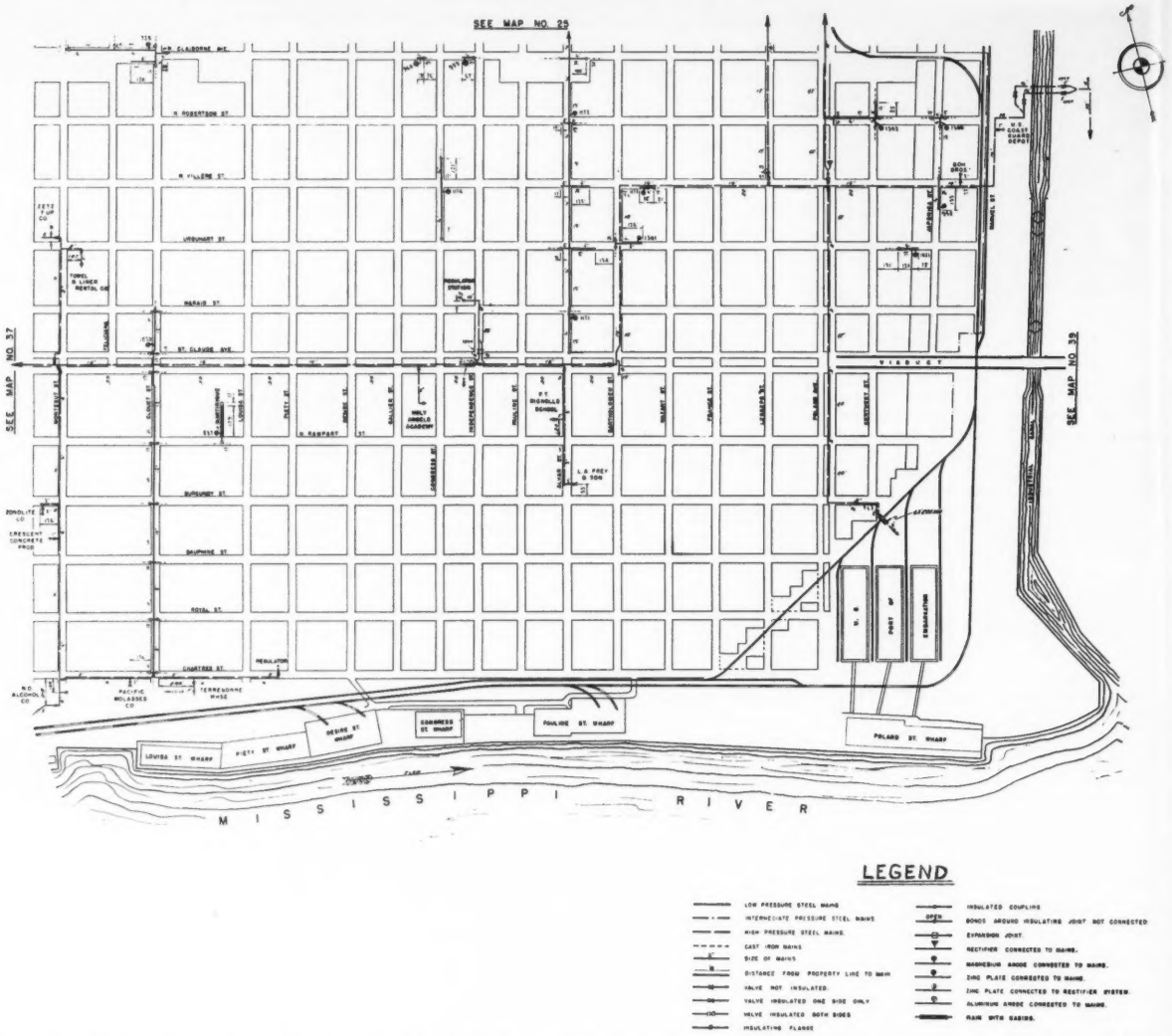

Figure 10—Section map showing cathodic protection of portion of New Orleans Public Service Inc. coated steel gas mains. Insulated joints between cast iron and steel are not bonded around. All other insulating joints are bonded around unless marked "open."

By means of the potentiometer arrangement, the resistance of the milliammeter can be nulled, or, for testing purposes, extra current from the battery can be forced into the earth from the anode. The latter feature is useful in computing anode resistance to earth when the normal anode current is too small for accurate computations.

In addition to the galvanic anode test set mentioned above, other useful instruments are: (a) Shepard Soil resistivity rods, (b) ordinary low resistance (400 ohms per volt) direct current multi-range voltmeter, (c) direct current ammeter, (d) high resistance multi-range direct current voltmeter, (e) direct current milliammeter, (f) inexpensive ohmmeter, voltmeter, ammeter combination AC and DC meter such as those used by radio and television technicians, (g) a current interrupter, and (h) a pipe locator tone set, preferably one with an interrupted tone. The latter set is very useful in locating accidental contacts between underground mains, short circuited insulated joints, and so forth.

Recording millivoltmeters and recording high resistance voltmeters are valuable for determining effects produced by various stray currents, and for studying other phenomena.

All cathodically protected steel gas mains are shown on a series of section maps, together with pertinent information on size and location. Rectifiers and insulated joints are also shown, as are anodes, whether operating alone or in parallel with rectifiers. A typical scaled section map is included for demonstration (Figure 10).

Operation of the Cathodic Protection System

If really satisfactory results are to be obtained from a cathodic protection system, considerable vigilance in periodic testing of the system will be required. It is folly to design and install a system and expect it to accomplish results almost completely unattended. Periodic rectifier surveys, galvanic anode, and continuity surveys are required for optimum performance. It is necessary to maintain the system at

TABLE 2—Typical Data Sheet From Galvanic Anode Survey (Zinc Anode Showed Good Performance)

Date	Time		1-2 Gas to Water (A) Volts	1-3 Gas to Anode (B) Volts	1-4 Gas to $CuSO_4$ (C) Volts	2-3 Water to Anode (D) Volts	2-4 Water to $CuSO_4$ (E) Volts	3-4 Anode to $CuSO_4$ (F) Volts	Total Anode Output (G) MA.	Resistance: Anode to Gas △B .001G OHMS	Resistance: Anode △D .001G OHMS	Resistance: Gas △A .001G OHMS	Water Tied to Gas: Anode Output (H) MA.	Water Tied to Gas: 3-4 Anode to $CuSO_4$ (K) Volts	Water Tied to Gas: Anode Resist. △K .001H OHMS	Curr. Req'd. for −1.00V to $CuSO_4$ MA.	
12/5/45	2:00pm	Off	−.26	+.20	− .86	+.465	− .62	−1.10						−1.10			
		On	−.33	0	− .96	+.360	− .62	− .96						− .74			
		Diff.	−.07	−.20	− .10	−.105	0	+ .14	22	9.1	4.8	3.2	85	+ .36	4.2		
11/14/47	3:55pm	Off	+.18	+.21	− .87	+.06	−1.00	−1.10						−1.10			
		On	+.07	0	−1.00	−.06	−1.00	−1.00						−1.05			
		Diff.	−.11	−.21	− .13	−.12	0	+ .10	25	8.4	4.8	4.4	9	+ .05	5.6		
3/12/48	12:30pm	Off	−.02	+.21	− .83	+.22	− .81	−1.05						−1.05			
		On	−.10	0	− .95	+.10	− .81	− .95						− .85			
		Diff.	−.08	−.21	− .12	−.12	0	+ .10	15.5	13.5	7.7	5.2	24.5	+ .20	8.2	37.2	R=4.6
6/14/50	2:40pm	Off	+.06	+.20	− .86	+.15	− .90	−1.07						−1.07			
		On	−.05	0	− .96	+.06	− .90	− .96						− .38			
		Diff.	−.11	−.20	− .10	−.09	0	+ .11	16.0	12.5	5.63	6.89	100	+ .69	6.9	19.5	R=7.18
2/13/52	10:30am	Off	−.08	+.16	− .90	+.24	− .82	−1.05						−1.05			
		On	−.14	0	− .96	+.14	− .82	− .96						− .53			
		Diff.	−.06	−.16	− .06	−.10	0	+ .09	16.0	10.0	6.25	3.75	100	+ .52	5.2		
3/25/53	1:10pm	Off	−.17	+.15	− .85	+.32	− .67	−1.00						−1.00		(To 2.0V)	
		On	−.23	0	− .91	+.23	− .67	− .91						− .35			
		Diff.	−.06	−.15	− .06	−.09	0	+ .09	12.5	12.0	7.2	4.8	100	+ .65	6.5	210	R=5.5

Location of Anode: Tchoupitoulas near Melpomene.
Type Anode: Zinc; no artificial backfill.
Section No.: 35.
Anode No.: 75.
Date Installed: 6/3/38. Anode was still functioning satisfactorily in 1955.
Remarks: Section protected consisted of 250 feet of 4-inch steel.

TABLE 3—Typical Data Sheet From Galvanic Anode Survey (This Zinc Anode Went Passive)

Date	Time		1-2 Gas to Water (A) Volts	1-3 Gas to Anode (B) Volts	1-4 Gas to $CuSO_4$ (C) Volts	2-3 Water to Anode (D) Volts	2-4 Water to $CuSO_4$ (E) Volts	3-4 Anode to $CuSO_4$ (F) Volts	Total Anode Output (G) MA.	Resistance: Anode to Gas △B .001G OHMS	Resistance: Anode △D .001G OHMS	Resistance: Gas △A .001G OHMS	Water Tied to Gas: Anode Output (H) MA.	Water Tied to Gas: 3-4 Anode to $CuSO_4$ (K) Volts	Water Tied to Gas: Anode Resist. △K .001H OHMS	Curr. Req'd. for −1.00V to $CuSO_4$ MA.	
12/17/45	1:30pm	Off	−.275	+.22	− .880	+.535	−.56	−1.100						−1.100			
		On	−.510	0	−1.065	+.535	−.56	−1.065						− .695			
		Diff.	−.235	−.22	− .185	0	0	− .035	0.6	—	—	—	16	+ .405	25.3		
8/11/47	4:15pm	Off	−.115	+.34	− .68	+.455	−.578	−1.02									
		On	−.350	0	− .91	+.355	−.578	− .91									
		Diff.	−.235	−.34	− .23	−.100	− 0	+ .11	3.5	97.2	28.6	67.1				5	R=64
3/29/50	3:15pm	Off	+.06	+.26	− .46	+.21	−.52	← − .74	←					− .74	↓	(To 1.6V)	
		On	−.09	0	− .61	+.09	−.52	− .61						− .53			
(New anode needed)		Diff.	−.15	−.26	− .15	−.12	0	+ .13	0.7	—	—	—	1.2	+ .21	175	15	R=76
8/ 6/51	11:30am	Off	−.27	+.28	− .80	+.56	−.52	−1.09						−1.09			
		On	−.56	0	−1.09	+.56	−.52	−1.09						− .24			
(New Anode)		Diff.	−.29	−.28	− .29	0	0	0	0.3	—	—	—	100	+ .85	8.5		
10/13/52	1:45pm	Off	−.25	+.30	− .72	+.55	−.48	−1.02						−1.02		(To 2.0V)	
		On	−.51	0	− .98	+.51	−.48	− .98						+ .16			
		Diff.	−.26	−.30	− .26	−.04	0	+ .04	2.3	130.4	17.4	113.0	100	+1.18	11.8	11	R=116
6/ 1/54	1:00pm	Off	−.45	+.19	− .91	+.64	−.46	−1.10						−1.10			
		On	−.64	0	−1.10	+.64	−.46	−1.10						+ .22			
		Diff.	−.19	−.19	− .19	0	0	0	0.1	—	—	—	100	+1.32	13.2		

NOTE: Arrows Indicate Anomalies.
Location of Anode: Frenchmen between Senate and Caton.
Type Anode: Zinc; No artificial backfill.
Section No.: 6
Anode No.: 46.
Date Installed: 6/8/45; no artifical backfill.
Remarks: Handhole was found destroyed on 8/11/47. On 9/1/50 new anode was installed in artificial backfill.

good potentials, and this cannot be accomplished if: (1) the rectifier units or the anodes are not operating, (2) the ground beds have developed high resistance, (3) accidental contacts exist between the protected system and other bare foreign structures, or (4) bond wires are broken.

It has been found that the most frequent causes of trouble are in the development of accidental contacts, and the short circuiting of insulated couplings between the steel mains and the bare cast iron gas mains. Relatively little trouble is encountered with the rectifiers or with the galvanic anodes.

Cost of Cathodic Protection

It is difficult to obtain all of the data necessary for a rigorous analysis of the economics of cathodic protection on a coated gas system. For instance, coating costs on mains laid many years ago would

TABLE 4—Typical Data Sheet From Galvanic Anode Survey (Zinc Anode Had Accidental Contact on System)

Date	Time		1-2 Gas to Water (A) Volts	1-3 Gas to Anode (B) Volts	1-4 Gas to $CuSO_4$ (C) Volts	2-3 Water to Anode (D) Volts	2-4 Water to $CuSO_4$ (E) Volts	3-4 Anode to $CuSO_4$ (F) Volts	Total Anode Output (G) MA.	Resistance: Anode to Gas △ B .001G OHMS	Resistance: Anode △ D .001G OHMS	Resistance: Gas △ A .001G OHMS	Water Tied to Gas: Anode Output (H) MA.	Water Tied to Gas: 3-4 Anode to $CuSO_4$ (K) Volts	Water Tied to Gas: Anode Resist. △ K .001H OHMS	Curr. Req'd. for —1.00V to $CuSO_4$ MA.	
5/17/48	2:20pm	Off	—.13	+ .44	— .66	+.59	—.49	—1.10						—1.10			
		On	—.59	0	—1.10	+.59	—.49	—1.10						— .90			
		Diff.	—.46	— .44	— .44	0	0	0	1.3	338	—	354	35	+ .20	5.8	-	
3/1/50 (Contact here)	2:30pm	Off	0	+ .50	— .59	+.50	—.58	—1.10	←↓			↓		—1.10		(To 0.7V)	↓
		On	—.08	0	— .68	+.09	—.58	— .68	67.0	7.46	6.12	1.19	75	— .62	6.4	240	R=.3
		Diff.	—.08	— .50	— .09	—.41	0	+ .42						+ .48			
6/6/51 (Contact Cleared)	12:01pm	Off	—.16	+ .375	— .70	+.525	—.545	—1.06						—1.06		(To 1.10V)	
		On	—.46	0	—1.00	+.465	—.545	—1.00						— .78			
		Diff.	—.30	— .375	— .30	—.060	0	+0.06	7.2	52.1	8.3	41.7	44	+ .28	6.4	10	R=40
6/10/52	12:40pm	Off	—.17	+ .25	— .73	+.47	—.505	—1.02						—1.02		(To 2.0V)	
		On	—.43	0	— .98	+.43	—.505	— .98						— .17			
		Diff.	—.26	— .25	— .25	—.04	0	+ .04	4.9	51.0	8.2	53	100	+ .85	8.5	30	R=4.
5/24/54	4:07pm	Off	—.38	+0.19	— .88	+.56	—.51	—1.06						—1.06			
		On	—.53	0	—1.03	+.53	—.51	—1.03						+ .04			
		Diff.	—.15	— .19	—0.15	—.03	0	+ .03	2.5	76	12	60	100	+1.10	11.0		
5/24/55	11:20am	Off	—.36	+ .20	— .90	+.56	—.54	—1.10						—1.10			
		On	—.52	0	—1.06	+.52	—.54	—1.06						+ .12			
		Diff.	—.16	— .20	— .16	—.04	0	+ .04	2.6	76.9	15.4	61.5	100	+1.22	12.2		

NOTE: Arrows Indicate Anomalies
Location of Anode: Bellaire Drive between Hedwige Lane and Marguerite.
Type Anode: Zinc; artificial backfill.
Section No.: 1.
Anode No.: 420.
Date Installed: 3/22/48.
Remarks: Section protected consisted of 318 feet of 6-inch steel main.

be most difficult to secure, but since the coatings must be considered as a necessary adjunct to cathodic protection, fixed costs on investment in coatings must be considered as a portion of the cost of cathodic protection. So also should be included fixed costs on other component parts of the cathodic protection system, such as insulated joints, bond wires, handholes, anodes, electrical testing instruments, and so forth. These figures, unfortunately, are not readily obtainable. Power costs for rectifiers also must be included if a full analysis is to be made. The rectifier services are unmetered, hence an estimate of power costs would be required if this phase of the cost were to be included. It is felt that since the rectifier currents are small the power costs would be small in comparison with fixed costs on the coating.

An attempt was made to compare known available costs of applying cathodic protection with the installation cost of that portion of the gas system under protection, with full recognition given to the fact that the omission of the data on fixed costs and power costs would result in inaccurate economic picture. This was done for the year 1954. Included in the cost of cathodic protection for this analysis were:

1. Engineering Department costs for routine surveys, location of accidental contacts, all miscellaneous testing (administrative overhead expenses omitted).
2. Gas Department charges for all time and material charged against cathodic protection (this includes removal of contacts, relocation or replacement of handholes, replacement of deteriorated anodes, rectifier ground beds, and defective insulated joints, installation of anodes or insulated joints which were not part of the original construction job). Costs of new rectifiers and new ground beds are included here, these items being relatively small; as such they are customarily charged against maintenance rather than capital.

For 1954, the annual costs enumerated above were 0.55 percent of the installed cost of the system under protection. A similar analysis made about five years ago disclosed substantially the same percentage figure.

Formerly, the steel pipe used was of a heavier weight than actually required for pressure or physical strength, the excess thickness being specified for reasons of corrosion. The cathodic protection system worked well, no corrosion leaks or failures having occurred despite very corrosive soils. Because of this performance, it was found feasible to reduce pipe wall thicknesses on pipe sizes from 4-inch through 20-inch by approximately 20 percent, resulting in a net savings on pipe alone of approximately $50,000 per year.

Educational Programs

Smooth and satisfactory performance of the cathodic protection program has been facilitated by the adoption of a program of information and education directed to the Gas Department, from the General Superintendent to the foremen and to the laborers. This program included fairly frequent forums and seminars with the keymen and division heads. The fundamentals of corrosion were explained to them in non-technical language. Points covered included how a rectifier works, how a galvanic anode works, the theory of cathodic protection, why it is

important to install mains in such a manner as to minimize chances of future contacts developing, why it is important to handle coated pipe with reasonable care so as to avoid damaging the coating, why it is necessary to use care in assembling insulated joints, etc.

A manual of good practices in handling and installing coated pipe was prepared and distributed to the field crews. This educational program has paid off well. Because of the educational program, a smaller number of personnel for inspection work and for subsequent corrosion testing has been made possible, and the over-all program has operated with smoothness and efficiency.

Summary

Results secured with cathodic protection have been good. No corrosion leaks have occurred on the cathodically protected steel gas mains. It appears reasonably certain that with the proper design, application, and maintenance of cathodic protection, the useful life of a coated steel gas main can be prolonged indefinitely, as far as corrosion is concerned. In New Orleans, it has been found that the successful operation of cathodic protection is materially aided by the observance of the following procedures:

1. Secure reasonably good coating on the mains to be protected.
2. Maintain the systems to be protected electrically continuous, and free from electrical contact with other metallic subsurface structures.
3. Maintain the electrical potential of the systems to be protected at least —0.85 volt to a copper sulfate reference electrode placed in the earth.
4. Maintain continuous operation of the device furnishing the current for cathodic protection.
5. Generally use many small, rather than a few very large, units for furnishing the cathodic protection currents. This minimizes problems of cathodic coordination.

Any discussion of this article not published above will appear in the June, 1957 issue.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in Corrosion will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

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Discussions will be reviewed by the editor of Corrosion and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of Corrosion, 1061 M & M Bldg., Houston 2, Texas.

The Biological Aspects of Attack on Creosoted Wood by Limnoria*

By CAROLYN BECKMAN,(1) R. J. MENZIES(2) and C. M. WAKEMAN(3)

Abstract

A study was made of the animal specimens found in samples of creosoted and non-creosoted Douglas fir pilings. The species causing the attack on the wood was identified as *Limnoria tripunctata*. Data are given to show the relationship of treated to untreated samples with regard to animal size, population density and reproduction capabilities. Pollution is discussed as a possible factor in the growth of *Limnoria* populations. Data are given to show changes of fractionation characteristics with time for creosote injected into pilings. 3.3.3

Introduction

IT HAS BEEN known for centuries that *Limnoria* eats wood. It has been only in recent years, however, that particular attention has been focused upon attacks by the animal on treated wood.[1] Today there is great concern about the species causing the attack on creosoted wood, the kind of creosote used, and methods which might be devised to stop such depredations. Except for certain laboratory evaluations,[2, 3] very little knowledge is available on the effect of the creosote treatment on animals in nature.

The authors wanted to know whether or not the animals were thriving in creosoted wood as well as they were in non-treated wood. It was believed that such data might give clues as to the efficacy of the treatment. From the works of Menzies[4] and Johnson and Menzies[5] norms or standards of population development were available which could be used to compare results.

Materials

Samples of creosoted piling (Figures 1 and 2) from the East Channel at Berth 57 from Los Angeles Harbor, California, were used in tests. Ecological studies made by Mr. Wakeman and his staff show that there was some pollution in the area although the dissolved oxygen content of the surface water did not fall below 2.7 parts per million (ppm) for the year 1955 (Table 1).

The creosote injected into the piling showed an original analysis that meets the existing AWPA standard for Grade I creosote (Table 2). Table 3 gives the fractionation characteristics after seven years.

The pilings were installed in 1949 and were very heavily attacked by 1956 at which time they had to be replaced. The wood was seasoned Douglas fir which had received a minimal treatment of coal tar creosote amounting to 16 pounds of creosote per cubic foot of timber with the full cell process.

Figure 1 shows sections of an attacked pile. It is of interest to note that the creosoted shell has been destroyed in some places and that the attack has proceeded with vigor into the untreated core of the pile.

The species causing the attack has been identified by the authors as *Limnoria tripunctata* Menzies.[1]

Biological Analyses

Samples amounting to several square inches of wood were removed from the pile section shown in Figure 2. These samples were taken from two places: from the creosoted shell and from the untreated core. All animal specimens were removed and studied with regard to their size, sex, and reproductive capacity as measured by the eggs produced and by the number of young present. The samples were collected during May 1956.

A total of six square inches of creosoted sample and six and one-half square inches of untreated sample were examined.

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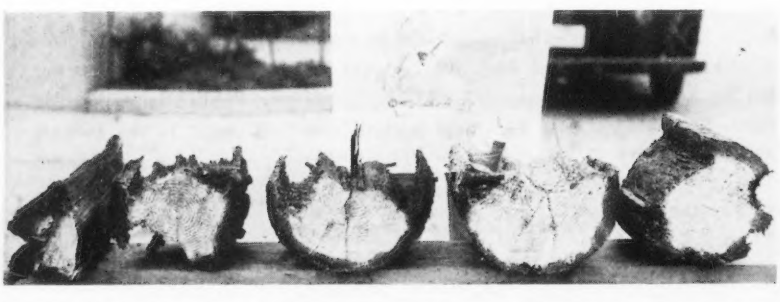

Figure 1—Results of *Limnoria* attack on several creosote treated Douglas fir piles during seven years' exposure in Los Angeles Harbor.

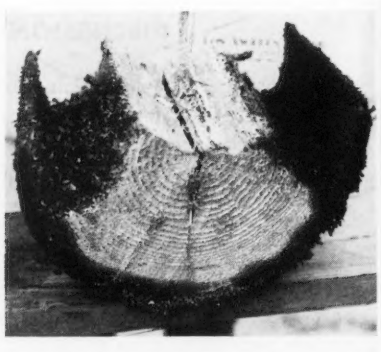

Figure 2—Closeup of Douglas fir piling attacked by *Limnoria*.

TABLE 1—Marine Ecological Conditions for the Year 1955 Near Attacked Piling, Los Angeles Harbor[1]

MONTH	Transparency (in Ft.)	Dissolved Oxygen at 20 Ft. (in ppm)	Sulf. at 20 Ft. (in ppm)	Temperature at 20 Ft. (in Degrees F)	Dissolved Oxygen at Surface (in ppm)	Sulf. at Surface (in ppm)	Temperature at Surface (in Degrees F)
January	14.0	6.0	None	56.0	2.8	None	56.1
February	10.0	5.9	None	54.0	4.9	None	58.2
March	12.0	7.3	None	58.6	4.9	None	62.1
April	12.0	8.4	None	58.2	7.0	None	59.9
May	7.0	6.8	None	58.8	6.4	None	57.8
June	9.0	6.0	None	62.2	6.0	None	65.0
July	11.0	6.6	None	64.5	5.6	None	67.2
August	9.5	6.5	None	66.0	5.5	None	68.8
September	6.5	5.8	None	63.0	5.4	None	70.0
October	14.0	4.8	None	61.0	2.7	None	65.0
November	9.2	4.3	None	62.0	3.0	None	64.0
December	12.0	3.6	None	56.2	2.9	None	58.0

[1] Data courtesy of Los Angeles Harbor Department.

TABLE 2—Original Fractionation Characteristics of Creosote Injected Into Piling Which Became Attacked[1]

Specific Gravity at 100 F		1.105
Distilled at:	170	None
	200	None
	210	None
	235	5.23%
	270	23.09%
	315	38.54%
	355	58.52%
	Residue	40.52%

[1] Los Angeles Harbor Department Lab. No. 1871 (1949).

TABLE 3—Fractionation Characteristics of Creosote Seven Years After Injection Into Piling (1956)[1]

Specific Gravity at 100 F		1.08
Distilled at:	170 F	None
	200 F	None
	210 F	None
	235 F	7.64%
	270 F	25.97%
	315 F	55.02%
	355 F	81.00%
	Residue	18.67%

[1] Creosote Analysis Los Angeles Harbor Department Lab. No. 8548.

TABLE 4—Limnoria Populations in Creosoted and Uncreosoted Parts of Attacked Piling

SIZE CLASS	CREOSOTED SAMPLES			UNTREATED SAMPLES		
	Young	Males	Females	Young	Males	Females
1	4	0	0	55	0	0
2	13	0	0	29	0	0
3	4	0	0	9	0	0
4	0	0	0	7	4	3
5	0	6	5	0	10	12
6	0	5	2	0	9	16
7	0	23	10	0	44	41
8	0	24	15	0	25	50
9	0	5	11	0	9	15
10	0	2	0	0	0	1
Total	21	65	43	100	108	131
% of Total	16	50	33	29	31	38

	Creosoted Samples	Untreated Samples
Total Examined	129	339
No./Inch²	21	52
Ratio young/adult	.19	.42
Average brood size	5.4	6.3
Percent females gravid	33	19
Mean size class of adults	7.4	7.2

Results

Population Density

The creosoted samples showed a population density of 21 animals per square inch while the density in the untreated sample was 52 animals per square inch (see Table 4).

Reproduction

Females from the creosoted sample had an average of 5.4 eggs per brood pouch. Thirty-three percent of the sexually mature females were gravid. Females from the untreated samples had 6.3 eggs per brood pouch. Nineteen percent of the sexually mature females were gravid.

Size

The average size class of adult animals from both samples was about the same (7.4 creosoted sample, 7.2 non-creosoted sample).

Reproductive Capabilities

The realized reproductive performance (rrp) of a population may be measured in the number of surviving young at a given time.

The number of young produced by the population from the creosoted wood was 50 per each 100 sexually mature females. Those from the non-creosoted sample produced 76 young per 100 females (see Table 5).

If the ratio of young per 100 adult females of a resident population from San Diego harbor is taken as a relative growth ratio of 1.00, then a standard is available with which to compare results.

A one month migrant population shows the lowest order of relative growth, namely 0.01. This would be expected from previous knowledge that the incubation period for a brood is about one month in duration.[4, 5] The population from the creosoted sample from Los Angeles showed a relative growth value of 0.11 and that from the untreated part a comparable low relative growth value of 0.17. In both cases the populations show internal growth but at a relatively low rate.

Pollution as a Possible Factor

In view of the low relative growth values for both Los Angeles populations which were subject to identical microecologic conditions as compared with the high relative growth values of the San Diego populations, it is suspected that here a sensitive biological index of the effects of pollution may have been found. The adequate evaluation of this possibility would be a considerable task and it is suggested as a possibility only in view of the great difficulties now facing the United States Government in evaluating the biologic effects of pollution. The San Diego populations were from a site hav-

ing an average of 1.00 ppm higher dissolved oxygen content than were the Los Angeles samples.

Temporal Changes in the Creosote

From the analyses (Tables 2-3) it would appear that the creosote changed little with respect to fractionation characteristics between 1949 and 1956. The most evident change seems to be a relative increase in the high temperature distillates with a corresponding relative loss of low temperature distillates. For some reason the percent of residue shows an increase with time. It is difficult to relate these data to biological attack on the pile. Other kinds of analyses may be more meaningful from the biological point of view.

The data possibly suggest that the low boiling point distillates, which have been somewhat depleted, may be the site of the most powerful preservative fraction(s). This suggestion is in accord with the findings of Hochman and his associates.[3]

Summary and Conclusions

1. *Limnoria tripunctata* does breed in creosoted wood in Los Angeles Harbor.
2. There was no significant difference in adult size or in the brood size of populations from creosoted and uncreosoted parts of the piling.
3. The population density of the creosoted sample was much less than that from the non-creosoted sample.
4. The relative growth value of the populations from the creosoted sample was less than that of the populations from the non-creosoted sample.
5. Points 3-4 suggest that the creosote treatment does markedly retard the attack through a lowering of the realized reproductive ability of the attacking population.
6. The relative growth value of *Limnoria* populations is suggested as a possible index of water pollution.

TABLE 5—Population Growth from Various Samples

SAMPLE	Harbor	Young per 100 Adult Females	Relative Growth Value
1 month migrant[1]	San Diego	4.7	0.01
2 month migrant[1]	San Diego	380.0	0.84
Resident population[1] non-creosoted portion of creosoted pile	San Diego	463.0	1.0
Non-creosoted sample	Los Angeles	76.0	0.17
Creosoted sample	Los Angeles	50.0	0.11

[1] From Reference 5.

Acknowledgment

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Any discussion of this article not published above will appear in the June, 1957 issue.

Corrosion Control System for Underground Cables in Conduit In a Stray Current Metropolitan Area*

By EDWARD P. TEALE

Introduction

THE FIRST intercity underground cable between Baltimore, Md. and Washington, D. C. was placed in 1912 along the Baltimore-Washington pike, known today as U. S. Route 1. The cable covering was plain lead sheath. The conduit consisted of four creosoted wood ducts, with two additional ducts in sections adjacent to urban areas.

A direct current traction system using overhead trolley wires and rail return, reinforced with negative feeders, was in operation between Washington, D. C. and Laurel, Md. at the time this conduit system was constructed. The geographical arrangement of tracks and cables in this area is shown in Figure 1. Two tracks were used from Washington to Branchville, a distance of about nine miles, with a single track to Laurel, a total distance of 19 miles from downtown Washington. Separations between tracks and cable varied from a few feet to about one-half mile. Thus, the cable immediately came under stray trolley current influence and some form of corrosion control was necessary. This was provided by wires for "natural" drainage from the cable to the negative busses of rotary converter stations at Ammendale, Riverdale and Eckington.

Figure 2 is a simplified map of the Hyattsville area. Streets and pipe grids have been omitted for clarity, since today they have become the equivalent of those in an urban area. The Baltimore and Ohio Railroad parallels the trolley and cable routes through this area and consists of two main and two siding tracks. It utilizes a DC signalling system supplied by wet cells. Throughout the years and as of today, the water and gas systems have not installed any drainage bonds to the Riverdale negative bus.

The drainage installed from Manhole 433 to the Riverdale Station, which is located in Hyattsville, Md., consisted of two No. 8 copper wires and was placed early in 1915. It delivered 30 amperes to the bus. There were some reversals in the direction of current flow over this drain and a "bond opener" or reversing switch was installed to prevent current being delivered to the cable. The drainage arrangement improved the sheath-to-earth potentials between Manholes 409 to 460, reducing but not completely clearing the exposure at Hyattsville.

Two additional cables, one in 1916 and one in 1918, were placed in the conduit system between Baltimore and Washington. Some exchange cables by this time, also had been placed in the Hyattsville area. This cable expansion and some increase in the water and gas pipe systems evidently caused an appreciable change in the subsurface network conditions. It was found that the original two No. 8 copper drainage wires from Manhole 433 to the Riverdale station required replacement with a No. 2/0 copper wire in order to maintain adequate electrolysis protection for the cable plant. Additional drainage was required after the fourth intercity cable and more exchange cables were placed in 1930. This was provided by reinforcing the No. 2/0 copper

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Abstract

Several miles of a main conduit route in a metropolitan area containing bare lead sheath telephone cables has been protected satisfactorily from stray current corrosion by a single 700,000 cm drainage wire. During and following the war period there was a rapid expansion of all types of underground utilities throughout the area. This altered the subsurface network conditions, causing the efficiency of the former protection to be greatly diminished.

Investigation indicated that in order to reestablish adequate protection by a single natural drainage connection, a much larger wire would be required. Further investigation indicated that by utilizing natural drainage from two points on the conduit system, thus providing the equivalent of distributed drainage, the size of wire for a natural drainage connection could be reduced appreciably.

As the result of additional study it was decided to utilize a controlled type of rectifier employing two stages of magnetic amplification. The primary purposes of such equipment were to overcome the IR drop in the drainage conductor and to limit the drainage current to the minimum value required by the natural potential difference between cable and earth. Employment of this equipment permitted the use of a distributed drainage arrangement, utilizing the original drainage facilities for one branch and a much smaller wire for the second branch.

This paper describes the system in detail, discusses the results obtained and the problems encountered in adjusting the rectifier equipment to obtain the desired operating characteristics. **5.2.1**

Figure 1—Map showing route from Baltimore, Md. to Washington, D. C.

wire with a No. 1/0 copper wire. This arrangement resulted in a current delivery to negative bus of about 125 amperes during peak trolley loads.

In 1934, a larger single copper drainage wire of 700,000 circular mils was installed to replace the previous wires, resulting in a 170 ampere peak drainage current to the Riverdale station.

About 1940, the trolley rails were removed between Laurel and Beltsville, and the Ammendale station was dismantled. Coincidentally, it was found that reversals in potentials to the Riverdale negative bus had decreased to a point which permitted the removal of the reversing switch in that drainage. The results of check tests made in connection with these changes showed that reasonably satisfactory protection was being provided the cables in the Hyattsville area approximately from Manhole 406 to 448.

Extensive housing development throughout all areas in Maryland adjacent to the District of Columbia occurred during the war period, 1940-1945, and in fact has continued ever since. This of course brought about further expansion of water, gas, and telephone services. The original conduit along U. S. Route 1 became inadequate and to accommodate the rapidly expanding exchange cable system in the Hyattsville area a reinforcing conduit was required. Such a structure, designated as the "R" run, was constructed in 1941 between Berwyn and Washington. It paralleled the original conduit and in some cases entered the same manholes. It increased the crossection from the original 6 ducts to 14-26 ducts in some sections. The cables housed in these two paralleling conduit systems, in general only a few feet apart, become effectively one unit, through their many interchanges and their sheath bonding arrangements. There are today four intercity cables and in some parts of the Hyattsville area as many as thirteen exchange and interoffice cables.

This overall expansion program again caused a considerable change in the sub-surface network conditions. The drainage installation at Manhole 433 was now competing with so many other paths that there was a marked decrease in sheath-to-bus potentials, in turn causing a diminution in drainage effects. The results of annual routine testing showed that progressively worse positive sheath-to-earth potentials were developing in the area.

Survey

In view of the increase in exposure conditions, a survey was initiated in 1949 coincidental with the removal of the rest of the single track between Beltsville and Branchville. The latter point is the present northern terminal of the two-track system, which continues to be supplied by the Riverdale station. This station is owned and operated by the Potomac Electric Power Company which sells direct current to the present trolley operator, the Capital Transit Company.

The survey showed first that a number of branch cables were in contact with other structures (e.g., power neutral in high and low voltage joint-use sections, building steel, water pipes in buildings, and grounded guys.) These took time to locate and correct. Next, under the then normal drainage operation at Manhole 433, high positive sheath-to-earth potentials were present, especially in areas where cables had been lost due to severe sheath corrosion. There have been thirteen section replacements classified as due to corrosion on the intercity cables alone between Manholes 426 and 460 in the years 1930 to 1949, plus one that had occurred prior to that time.

The upper part of Figure 3 shows the sheath-to-earth potentials and sheath currents observed in the Hyattsville area during this survey. Note the change in exposure conditions in the very close cable to trolley rail proximity area north and south of Manhole 456. The exposure conditions north of Manhole 445 diminish as the influence of the Manhole 433 drainage is reached. The exposure north of Manhole 433 becomes less severe due to greater separation from trolley rails and a slightly less complex subsurface network. The potential measurements shown were made using a lead plate as the earth contact electrode.

In the early part of this new investigation the traction company was asked to and did conduct a thorough inspection of rail bonding. Little repair work was needed. Checks along the cable route after bonding repairs showed no improvement in conditions.

Subsequent testing showed that, although there were some minor fringe effects due to the Eckington station (the next toward Washington from Riverdale), stray trolley current originating at the River-

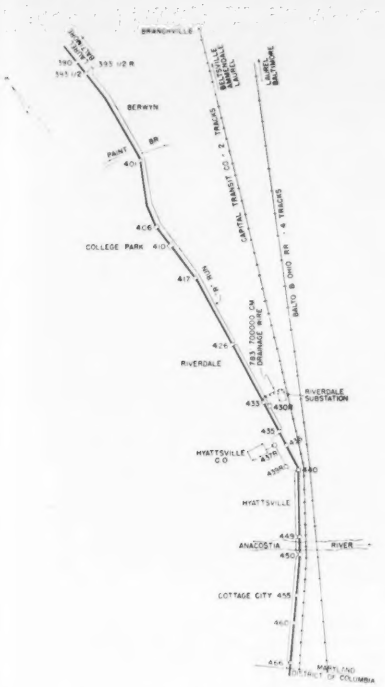

Figure 2—Map showing Baltimore-Washington cables in the Hyattsville area. Approximate location of rail and cable systems are shown.

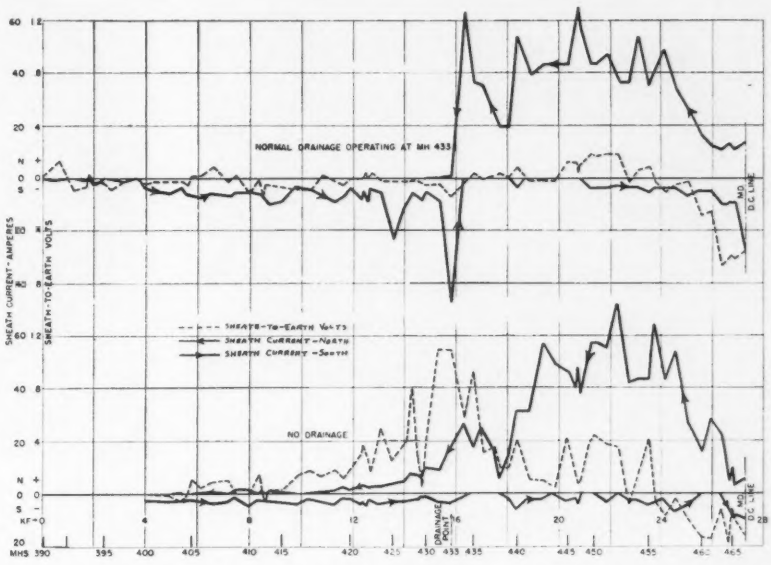
NORMAL DRAINAGE OPERATING AT MH 433
NO DRAINAGE
SHEATH-TO-EARTH VOLTS
SHEATH CURRENT-NORTH
SHEATH CURRENT-SOUTH
SHEATH CURRENT - AMPERES
SHEATH-TO-EARTH VOLTS
MD. D.C. LINE
DRAINAGE POINT
MHS 390 395 400 405 410 415 420 425 430 433 435 440 445 450 455 460 465

Figure 3—Exposure intensity chart of Baltimore-Washington cables in the Hyattsville area.

dale station was the primary cause of the exposure. The decision was reached that since major revisions in the existing protection arrangement were indicated, the area should be resurveyed without benefit of drainage and be treated as a new problem. The results of this resurvey are shown in the lower part of Figure 3 for comparative purposes.

Stray railway current problems usually employ "natural" drainage as a mitigation measure. Any properly designed "natural" drainage arrangement will utilize a drainage conductor no larger than required to deliver at all times the correct amount of current to the negative bus of the appropriate trolley supply station. The size of such a conductor is a direct function of the available structure-to-bus potentials, the internal resistance of the structure-earth-bus path (commonly referred to as the "structure-to-bus coupling"), the amount of drainage current required, and the length of conductor from structure to bus.

Experimental drainage tests at Hyattsville showed that correct drainage could not be provided via a single wire from the old drainage point, Manhole 433. A current delivery to bus of 180-200 amperes peak would be needed for minimum effective clearance. The cable-to-bus potentials however had fallen to about 4 volts peak, compared to about 16 volts in 1934. Computations based on these factors showed that a wire of infinite conductivity would be required from Manhole 433 to the Riverdale bus. This of course was an impossibility.

Distributed Cathode System

The most favorable arrangement was found to be a distributed cathode system of three connections using copper wires of 1,000,000 circular mils from Manhole 433, 500,000 circular mils from Manhole 440 and 300,000 circular mils from Manhole 450, draining 100, 40 and 30 amperes, respectively. This arrangement could be expected to give minimum effective clearance between Manholes 410 and 455 as indicated by sheath-to-earth potential measurements. Cooperative tests with other utilities showed that this arrangement should have no detrimental effects on their plants. The Baltimore and Ohio Railroad people moreover indicated informally that such an arrangement would actually improve existing conditions on the railroad signalling system.

It appeared logical to use a pole line along the trolley tracks in order to string the proposed 500,000 and 300,000 circular mils wires from the Riverdale station to Manholes 440 and 450, respectively. It was found however that this plan would be uneconomical due to the extensive amount of space rearrangement and pole replacement work which would be required on this line. An alternate routing for the proposed wires was then considered using the pole line carrying the existing 700,000 circular mils wire, thence via conduit to Manholes 440 and 450. Duct space for these proposed wires was available only as far south as Manhole 440. Thus, the distributed cathode system would be reduced to two connections; the provision of equivalent protection would require copper wires of at least 2,400,000 circular mils from Manhole 433 and about 600,000 circular mils from Manhole 440 for drainage currents of 100 and 80 amperes, respectively. The very large wire from Manhole 433

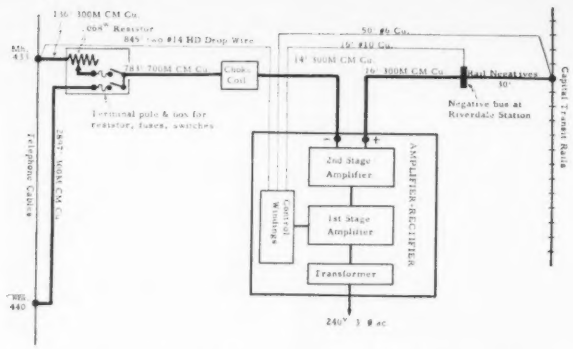

Figure 4—General layout of drainage system in 1955 for Baltimore-Washington cables in Hyattsville, Md.

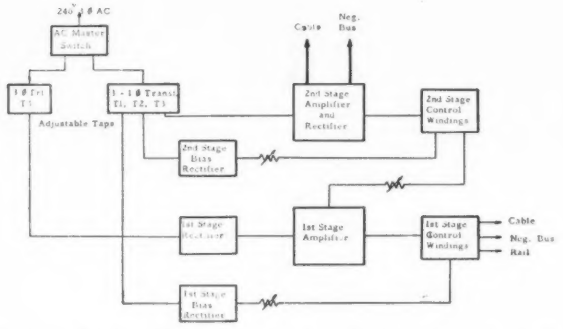

Figure 5—Position of AC power supply and component parts in the amplifier-rectifier circuit.

was considered too much copper to be supported on the existing pole line.

Final Arrangements

Oliver Henderson of the Ohio Bell Telephone Company once stated in a paper[1]: "The amount of current which constitutes correct drainage may vary considerably with the time of day due to frequent changes in the amount and direction of the stray earth current throughout the railway traffic cycle. The variations are due to the peaks in passenger loads and the related scheduling of the railway substation operation.

"It is evident that a rectifier used for forced drainage and adjusted to any given amount of output current would be correct for only a small portion of the total time. With a fixed output, over-drainage probably will occur during light railway loads and inadequate drainage may result during the peaks of traffic. The proper drainage could, however, be maintained by a rectifier whose output is automatically and continuously variable from zero to maximum under the control of the potentials of the structures being protected."

The specific situation covered by Mr. Henderson's paper is not radically different in principle from that at Hyattsville. It varies chiefly in the magnitude of stray current involved and the fact that it used an anode system not associated directly with the trolley system.

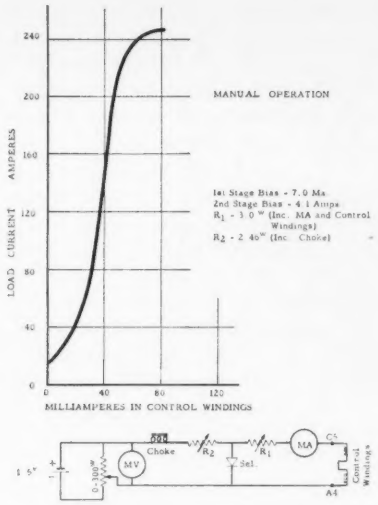

Figure 6—Load current versus current in control windings (manual operation).

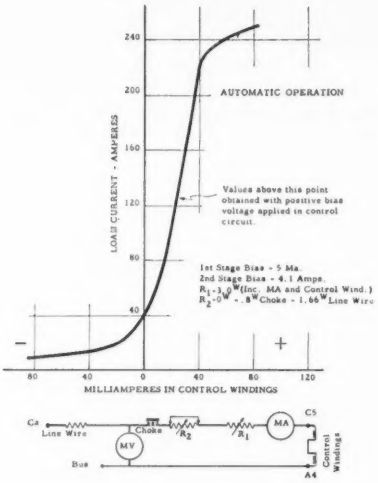

Figure 7—Load current versus current in control windings (automatic operation).

A review of the problem at Hyattsville indicated that the most economical solution would be the two connection distributed cathode arrangement, providing that some means could be found to reduce the IR drop in the drainage system and thus avoid the use of very large conductors.

Use of Magnetic Amplifier

A magnetic amplifier to control the output of a rectifier offers such a means. The arrangement uses no vacuum tubes or moving parts and under all normal conditions should remain trouble-free. It appeared the amplifier-rectifier arrangement would meet the conditions peculiar to the Hyattsville Area. Accordingly, such a unit was built, employing two stages of amplification to control a rectifier having a capacity of 250 amperes to work into a .1095-ohm load. It was designed and constructed to utilize the sheath-to-bus potentials for control of the output

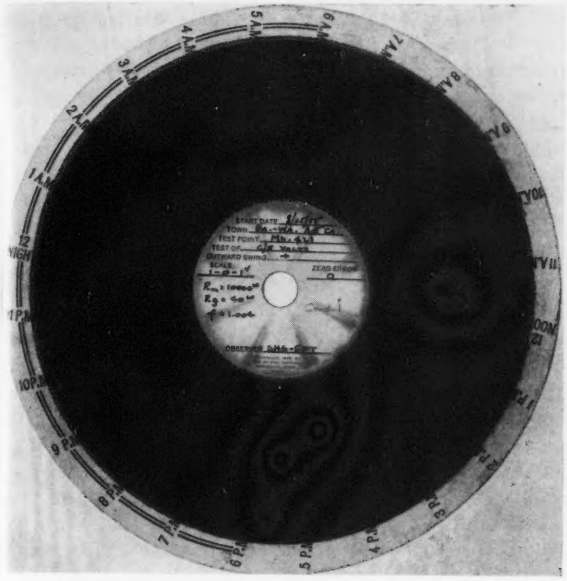

Figure 8—Typical sheath-to-earth potentials with amplifier-rectifier control windings connected to cable sheath at Manhole 433 and negative bus. Test point was at Manhole 421.

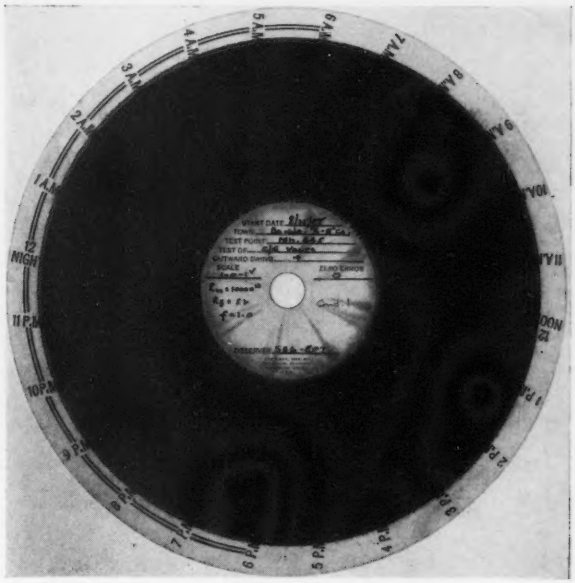

Figure 9—Typical sheath-to-earth potentials with amplifier-rectifier control windings connected to cable sheath at Manhole 433 and negative bus. Test point was at Manhole 445.

load current, and to permit the continued use of the existing 700,000 circular mil wire between Manhole 433 and the Riverdale bus. The complete amplifier-rectifier arrangement uses a three-phase 240 volt AC power supply.

Credit for the design work should be given to D. R. Werner of the Western Area office of the Long Lines Department of the American Telephone and Telegraph Co. The reactors and selenium stacks were supplied by one manufacturer. Other related equipment was supplied, and the final unit assembled and encased by another manufacturer. It proved impracticable to provide a single housing for the main unit and its associated choke coil. Thus, a separate housing was provided for the latter. It might be well to mention here that it is standard practice in connection with cathodic protection work for intercity telephone cables to provide a choke coil as part of the rectifier output circuit. The reasons for this will be given later.

As just mentioned, this equipment was designed to utilize the cable-to-bus potentials for control or triggering of the output load current. This necessitated a circuit having two separate earth contacts. Such an arrangement introduces the important consideration of eliminating any stray AC effects which might appear in the control circuit. A suitable filter will perform this function. Otherwise, half of the AC voltage or current wave will aid whatever DC control voltages or currents are present and tend to increase the rectifier output beyond that called for by the DC controls. The need to eliminate stray AC effects is present at all times, but becomes of greater importance during any shut down periods of the station to which compensating drainage of this type is installed. The Riverdale station was originally off the line from 3 to 5 AM and is now off from 1:30 to 5:00 AM.

Figure 4 is a simplified diagram of the overall drainage system finally adopted at Hyattsville. It shows the general relation of cables, drainage wires, trolley station, and the amplifier-rectifier. Figure 5 is a block diagram showing the position of component parts in the amplifier-rectifier circuit.

The completion of an installation of the magnitude involved here is likely to be delayed for a number of reasons. This case was no exception and the installation was not completed until July, 1955.

A transit strike was in progress in this area and the trolley system was not operating when the installation was ready for service. This offered a good opportunity to make performance tests under normal connected load or circuit resistance, in preference to a dummy load. It was found immediately in connection with such tests that another change had occurred in network conditions, as the connected load now measured .0775 ohm, or a decrease of nearly 30 percent in the design value of .1095 ohm. These values give some indication of the network changes taking place continually in this area. The network change cited could have proven serious if adequate controls had not been provided in the equipment to permit appropriate compensation.

The input versus output curve for a magnetic amplifier-rectifier usually has the appearance of a long, thin, slanting S, looking somewhat like the upward sweep of the hysteresis loop. Figure 6 is a plot of one of a number of performance tests made at Hyattsville showing this appearance. Generally the most efficient operation of such a unit is obtained when the equipment is worked on the straight line portion of the curve. Within the practical limitations of manufacture of this type of equipment, the curve of Figure 6 might be considered as almost ideal. Also, it shows the rectifier output rises rapidly with a small increase in the control current. It should be remem-

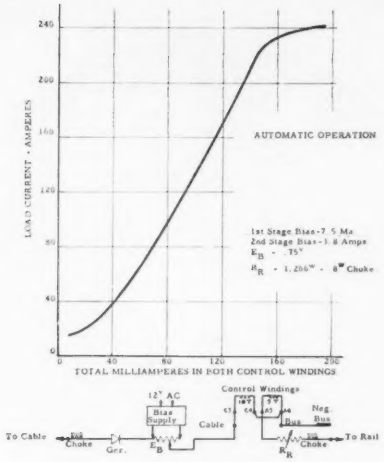

Figure 10—Load current versus current in control windings. Final control circuit arrangement is shown.

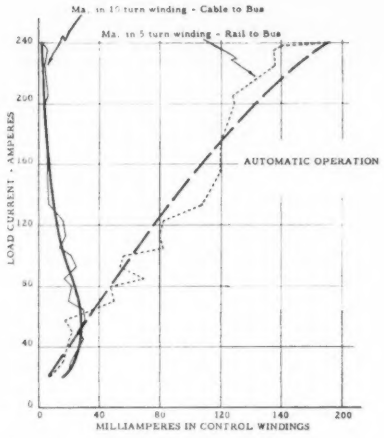
Ma. in 10 turn winding - Cable to Bus
Ma. in 5 turn winding - Rail to Bus
LOAD CURRENT - AMPERES
AUTOMATIC OPERATION
MILLIAMPERES IN CONTROL WINDINGS

Figure 11—Load current versus current in control windings. Same conditions, control circuitry and test data apply as for Figure 10.

bered, however, that all of the individual performance tests were made when the trolley system was idle, thus requiring manual control of the input currents. This manual control arrangement is shown in the diagram on Figure 6.

Automatic Operation

The trolley system was reactivated in August 1955. It was then found that the behavior of the equipment under automatic operation was radically different from that under manually controlled conditions. The rectifier output would rise to only about 100 amperes peak compared to the 180-200 ampere output required during periods of maximum trolley operation. Proportionately smaller outputs occurred during off-peak trolley operation.

Figure 7 shows a curve typical of behavior under automatic operation. In order to extend the curve to full load output it was necessary to apply an increasing positive bias voltage in the control circuit. The curve tends to match the ideal curve, but there is a shift too far to the negative side, when no positive bias voltage is applied. This indicates that more control voltage or current than was actually available from the normal sheath-to-bus potentials is required to produce the values of output current needed during peak load trolley operation. The net effect of this inadequate current delivery is non-cleared positive sheath-to-earth potentials as shown by Figures 8 and 9 of 24 hour recording meter charts taken in key manholes.

Determination of Correct Control Circuit Arrangement

Some means had to be found to meet the two conditions of proper current output during trolley peaks and when the Riverdale Station was idle. This of course was a matter of determining the correct control circuit arrangement, which might be thought of as a fairly simple procedure. Such was not the case, and it became a sizable problem to meet the two conditions. This was evidenced by the fact that, exclusive of small adjustments, such as in the first and second stage bias currents, a total of 21 control conditions were tried before a satisfactory arrangement was found. Among the schemes tried were: (1) various input filter circuits, (2) redivision of currents drained from Manholes 433 and 440, (3) the application of a positive bias voltage in the cable-to-bus control circuit, (4) the use of the sheath-to-earth potential at Manhole 433 as the control potential, and (4) splitting the first stage amplifier control windings between rail-bus and cable-bus with a small positive bias voltage in the cable-bus circuit. Each of these empirical arrangements required some determination of the effects on the sheath-to-earth potentials in at least key manholes. It was desirable in general to determine these from 24 hour recordings, which meant in some instances that as much as a day per arrangement was needed.

The circuitry of split control windings in the first stage amplifier gave the best overall rectifier operation (i.e., the drainage current requirements were met and varied in accordance with the trolley loads). Figure 10 shows the final control circuit arrangement, including AC filtering, and the associated input versus output curve, which is plotted from automatic operation data.

Figure 11 is just another way to show the same data and indicates that the higher output currents are controlled by the rail-to-bus voltage and the lower output currents by the cable-to-bus voltage. This relation is seen more sharply if Figure 11 is rotated 90 degrees counterclockwise. The resulting cable-to-earth potentials in manholes, as shown on 24 hour recordings, now took on much of the usual stray trolley current pattern, whereas with a perfectly balanced system, the pattern could be expected to be more of a "bullseye."

Figures 12 and 13 show typical recordings under the final control condition at the same two manholes shown previously in Figures 8 and 9.

Figure 14 indicates in chart form the effect finally achieved at manholes throughout the area. The chart shows the minimum and maximum sheath-to-earth

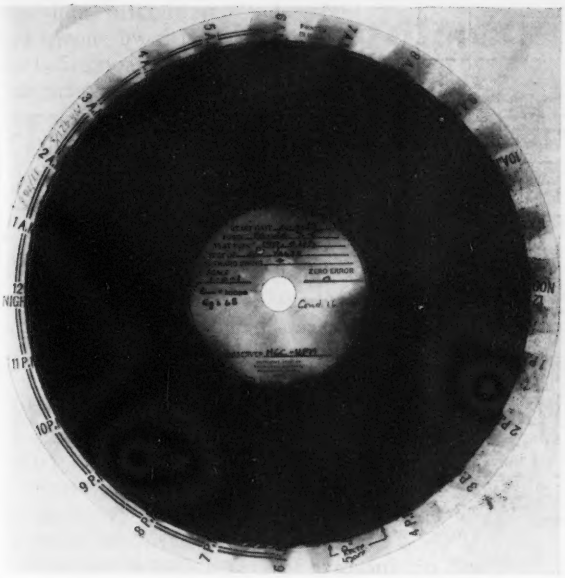

Figure 12—Typical sheath-to-earth potentials with amplifier-rectifier control windings divided and connected to cable sheath at Manhole 433 and negative bus, and trolley rail opposite Riverdale Station and negative bus.

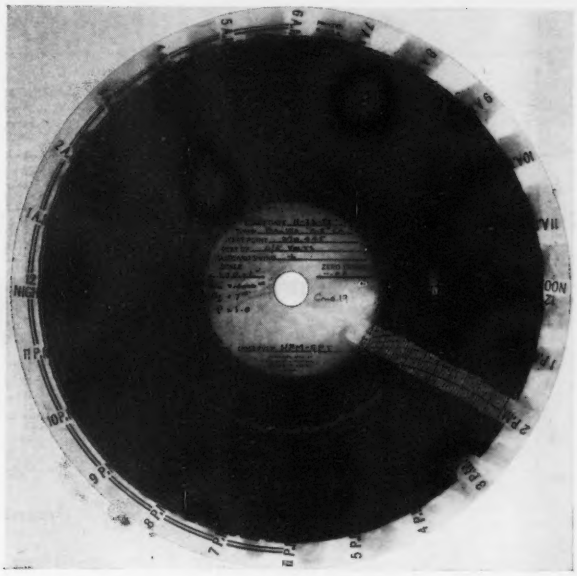

Figure 13—Typical sheath-to-earth potentials with amplifier-rectifier control windings divided and connected to cable sheath at Manhole 433 and negative bus, and trolley rail opposite Riverdale Station and negative bus.

potentials occurring during a car cycle. These potentials may have a fairly wide divergence at some manholes, however the average values are close to .1 to .3 volt negative at most manholes within the design area. It is considered that adequate protection has been afforded not only to the design area between Manholes 410 and 455 but well beyond each end or from Manholes 390 to 465.

The achievement of the "bullseye" effect, aforementioned, does not appear impossible. It seems unwarranted, however, as considerable additional testing time would be required and since there are reasonable indications the particular trolley system involved here may be discontinued.

Noise Considerations

Communication circuits may, under certain conditions, be affected adversely from a noise standpoint by the presence of harmonic frequencies in currents or voltages in nearby power or other circuits. Such harmonics may originate in some piece of equipment either generating or using power and be propogated over the power or other network. Their appearance as noise in the communication circuits is dependent upon the electrical dimensions of the particular situation.

One of the inherent characteristics of rectifiers is the generation of harmonics. These harmonics may be propagated over systems connected to both the AC and DC sides.

Harmonic output on the AC supply side of a rectifier can be propagated over the power supply network and may give rise to noise on any communication circuits exposed to the network. The need for harmonic suppression on the AC side depends, to a large extent, on the size of the rectifier and the size and capacity of the power network involved. Suppression, if required, can generally be obtained by use of capacitors or inductors or a combination of the two.

Harmonic output on the DC side of a rectifier, if severe enough, also may give rise to noise on any communication circuits exposed to the circuit connected to the rectifier output. This occurs because the rectifier output current is not a true direct current, but rather a unidirectional current comprised of a series of half sine waves. The need for harmonic suppression on the DC side depends in large measure on the magnitude of the output current. Again, if suppression is required it can generally be obtained by use of an inductor, commonly called a choke coil. Such a choke must of course be of correct inductance and have the current carying capacity of the rated DC output of the rectifier.

Any plant associated with rectifier operation for corrosion control forms directly an intimate part of the DC output circuit. When this plant is a telephone cable the resulting current impressed on the cable sheath could, through induction, produce objectionable noise in the telephone circuits in the cable. Thus, whenever consideration is given to the use of a rectifier, there arises immediately the question of noise influence on any communication circuits in the vicinity due to the harmonics generated by rectifier operation. Considerable apprehension concerning the possibility of high noise influence in the Hyattsville area was expressed because of the size of the rectifier proposed and the number of communication cables involved.

It appeared advisable to obtain some idea of the expected noise behavior of the complete amplifier-rectifier assembly planned for Hyattsville. Accordingly, influence measurements were made at the fac-

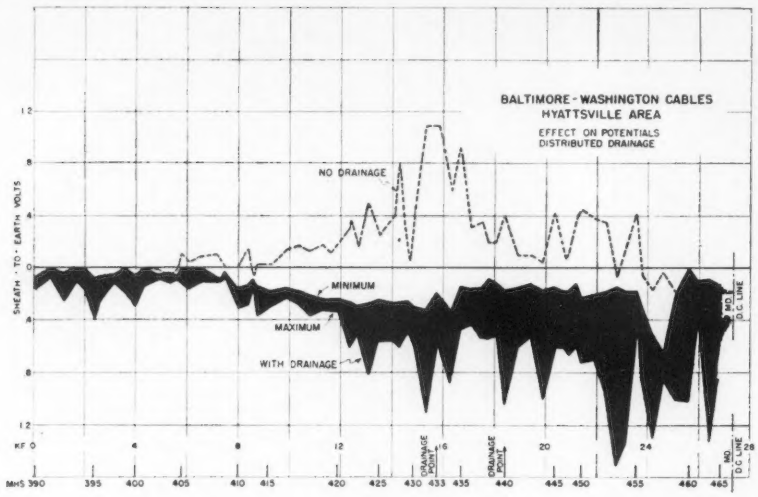

Figure 14—Effect achieved on manholes in Hyattsville area.

tory on both the AC and DC sides. The control current for these tests of necessity had to be supplied manually instead of from the normal cable-to-bus circuit.

Measurements on the AC side indicated that it might be necessary to give consideration to harmonic suppression measures. Tests made after installation in the field gave results comparable with those at the factory. No suppression measures seem warranted however due to the size and capacity of the power network to which the rectifier is connected.

Measurements on the DC side indicated that with the choke coil as constructed, fairly high 360 and 720 cycle components were present in the full load current. The manufacturer then constructed a new and larger choke (the one now in place). Field tests under both automatic and controlled operation have shown that while there are still some 360 and 720 cycle components present they are not creating objectionable noise in the various telephone cables involved in this case.

Conclusions

A few conclusions can perhaps be drawn from the foregoing as applicable to metropolitan areas where the subsurface network conditions are undergoing constant change:

1. Engineer into the design adequate controls to permit meeting changing network conditions. The chances are the network value will not increase and the amplifier-rectifier must therefore be adjustable to operate into smaller and smaller load resistance values.
2. Pre-determine as accurately as practicable the expected noise influence of the equipment. If the results are unfavorable be sure adequate filtering is provided.
3. Considerable patience, perseverance, time, and a number of tests will be required before achieving the results desired.

Reference

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Any discussion of this article not published above will appear in the June, 1957 issue.

The Corrosion of Steel In a Reinforced Concrete Bridge*

By R. F. STRATFULL*

Abstract

Studies were made to determine the cause of accelerated corrosion of reinforcing steel in a concrete bridge in a salt water environment. There was good reason to believe that macro-galvanic corrosion was involved.

Resistivity and corrosion cell ratio charts indicate that the resistivity of concrete decreases as the deterioration of the concrete increases. The lower resistivity measurements of the concrete in the anodic areas indicated that the anodic areas could have been created by the following factors: (1) a greater moisture content in the anodic areas, and (2) a greater sea salt content in the anodic areas.

Cathodic protection may offer a means of curbing corrosion but certain precautions should be taken. All available data indicate that in new installations in salt water environments, corrosion problems can be minimized by using a concrete formulation having minimum porosity and by a design having a maximum coverage of concrete over the reinforcing steel.

6.6.5.

Introduction

THE CORROSION of reinforcing steel encased in concrete has received scant attention, and with one known exception the mechanism has not been too clearly defined.[1] However, by employing accepted test methods, it is shown that under proper circumstances concrete acts as an electrolyte.

Results indicate that reinforcing steel in concrete exhibits the same general galvanic properties of corrosion as does steel in soil or aqueous solutions. Thus the corrosion studies performed in the laboratory of the Materials and Research Department of the California Division of Highways and on the San Mateo-Hayward Bridge, disclose no new or basically unique phenomena in the corrosion of the reinforcing steel. However, the widespread resultant deterioration of the concrete bridge members, which is manifested by spalling of the concrete, introduces problems that so far have proved to be extremely difficult to curb or nullify.

The major portions of this highway bridge consist of a reinforced concrete two-lane causeway which totals some seven miles in length. The structure was built in 1928-29 and was maintained under private ownership until 1951. On this latter date the unit was acquired by the State of California.

Spalling of Concrete

Starting about seven years after initial construction, an unexpected maintenance problem developed because of the excessive spalling of the concrete. Investigation disclosed that the spalling of the concrete was the result of accelerated corrosion of the reinforcing steel. Trouble was developing in scattered areas throughout the entire structure.

The areas showing the greatest attack were repaired by the original owners with shotcrete. Much of the underside area of the structure was painted with an asphaltic coating with the intention of excluding salt water spray, which appeared to be penetrating the appreciably porous concrete structure. Despite these initial preventive measures, the afflicted areas of corrosion increased progressively and were to be found in the concrete pilings, caps, diaphragms, main deck beams, and occasionally in the underside of the deck. For this reason a full scale study was undertaken by the California Division of Highways to establish the basic cause of the difficulties.

Water-Cement Ratio

In examining the history of the concrete structure, it was found that the water-cement ratio used at the time of construction, and the prevailing design criteria exceeded values that are now considered good practice. The high water cement ratio resulted in a relatively permeable concrete with the result that moisture and air were not effectively restricted from the steel. Likewise the portland cement used was not of a sulfate resistant type. Recent magnesia and sulfate tests of random samples of concrete indicate a minor increase in SO_3 (to be expected because of solubility of $CaSO_4 \cdot 2H_2O$); MgO, as percent of cement, increased from 1.67 to about 7 percent.

In the tests of the permeation of sea salts, it was found that the percentage of chlorides in the outer one inch of the concrete was as high as 0.31 percent of the dry weight of the mortar. The chloride concentration in concrete adjacent to corroded reinforcing steel was found to be as great as 0.86 percent of the dry weight of the mortar.

The concrete cover over the reinforcing steel was designed and built to a minimum thickness of two inches.

In general, the pervious nature of the concrete and the average high humidities which prevail in the area, and other associated physical factors such as insufficient concrete cover over the steel for the

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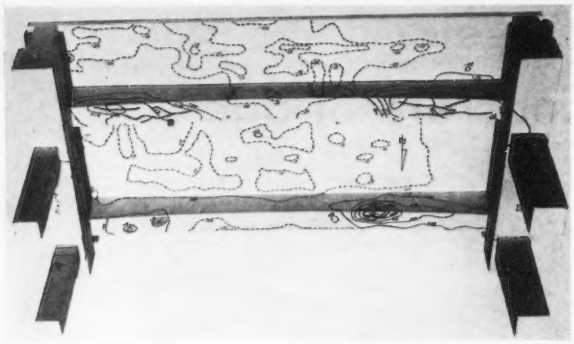

Figure 1—Typical equipotential contours of surface potential differences plotted on scale model of a half width of a span. Equipotential contours are plotted on under surface of scale model of left half of span 512. Dashed lines represent cathodic (non-corroding) voltages while straight lines depict anodic (corroding) voltages. Wavy lines represent cracks in concrete. Note that the cathodic areas are located in the deck and that the anodes are located in the bottom of the beams. Surface potential figures are actual readings in volts.

porous mix used, greatly complicated the corrosion problem. In fact the possibilities of macro-galvanic attack were suggested, similar to that of steel imbedded in the earth.

Concrete As An Electrolyte

The initial investigation which included both potential and resistivity measurements soon disclosed that the concrete in the structure was acting as an electrolyte. Over distances of several feet or more, potential differences on the surface of the concrete as great as approximately 0.45 volt could be detected. Those areas showing evidence of corrosion were generally entirely above the lower tide level and were always confined to the anodic regions.

In one of the various published reports concerning the causes of corrosion of steel there is a discussion[1] of a theoretical computation which, on the basis of salt content in a concrete cell, indicated that a potential of 0.45 volt could exist. This agrees closely with the measured potential differences found in the San Mateo Bay bridge structure.

Potential Measurements

Figure 1 is a picture of a scale model representing a half width of a typical span showing the underside of the structure. The solid lines on the model indicate anodic equipotential contours. In this particular span, as well as in many similar spans, the potential contours indicate that the deck is normally cathodic to the main beams supporting the deck. The equipotential contours shown in Figure 1 are not reinforcing steel to reference cell potentials. They are potential differences between two reference cells on the surface of the concrete. The potential differences are the result of galvanic current. When the surface potential differences, or gradients, were measured, one of the half cells was left in place during the complete measuring period and other cell was contacted to numerous places on the surface of the concrete.

Because of the high order of electrical contact resistance of the reference cells to concrete (in the order of 1000 to 100,000 ohms) and the estimated low current density flowing through the concrete, it was necessary to use a 50 meg ohm per volt vacuum tube voltmeter to limit the effects of instrumentation.

Reference Cells

Two types of copper sulfate reference cells were used. The first type consisted of a porous cup filled with a saturated copper sulfate solution and a pure copper electrode. This reference cell was left in place during the period of measurement.

The other type of reference cell was hand held and used to measure on overhead and vertical surfaces. This cell was constructed by filling a polyethylene bottle with saturated copper sulfate and a pure copper electrode.

Electrical connection was made to the copper electrode by bringing the thin copper electrode through the cork. Electrical junction to the copper sulfate solution was made by inserting a wick-filled glass tube through the cork to the solution. The external wicking was then placed in between the sponge used to actually contact the concrete and the wooden container used to hold the complete cell assembly.

A plexiglass handle was attached to the wooden container to prevent "electrical shorting" of the cell through the operator. Even so, it was found necessary to clean all lead wires and cells daily with fresh water to remove any accumulated salt film that could adversely affect the validity of the measurements.

Potential Surveys

Potential surveys were made on approximately 16 different spans of this bridge. On three specific beams in the structure potential gradients were taken, and the indicated anodic and cathodic areas were plotted as found. The concrete along the bottom of these three beams was then completely chipped away exposing the lower layer of reinforcing steel. The relationship between the anodic potential areas, concrete deterioration and galvanic attack on steel was completely confirmed in each case.

In some of the spans which have been repaired with shotcrete, potential measurements indicate that shotcrete encased steel becomes cathodic to non-shotcrete encased steel.

A potential survey was made on a rejected reinforced concrete pile abandoned at the time of construction of the San Mateo-Hayward Bridge. This pile, called Pile A in this study, was located approximately 25 feet north of the west end of the bridge; it had been left for an estimated 27 years in the tidal water zone at the bridge site. The concrete was cracked in the same typical manner as the piles in the bridge structure. The cracks were longitudinal, and the steel was corroding in the same manner as in the bridge.

Potential measurements were made on the top face of this pile. These surface potentials were drawn in equipotential contours at 0.01 volt increments and are shown on Figure 2. The potential measurements on this pile indicated that the corrosion of the steel is associated with a corrosion cell in which the

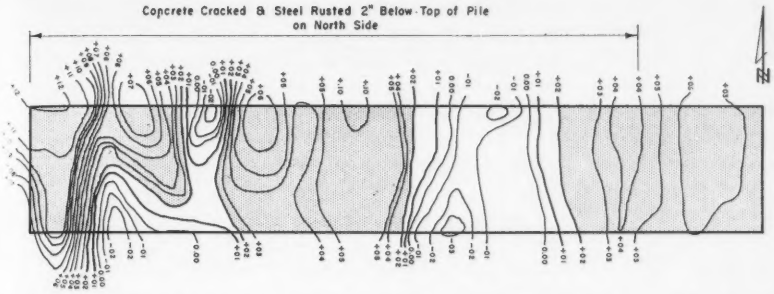

Figure 2—Equipotential contours of surface potential differences for Pile A (an abandoned reinforced concrete pile). Dotted sections of drawing represent anodic areas while white sections represent cathodic areas. Potentials are to Cu-$CuSO_4$ on concrete to a reference Cu-$CuSO_4$ on soil. Actual readings in volts. Scale is as follows: 1 inch = 8 feet longitudinally, 1 inch = 2 feet laterally.

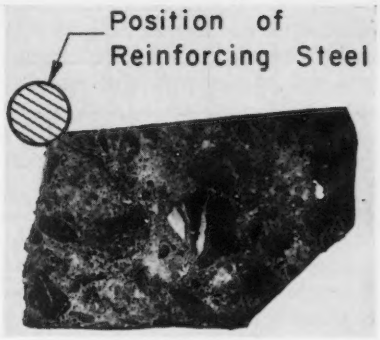

Figure 3—Concrete beam sample obtained from area of steel corrosion and concrete spalling. Note crack in concrete which started at the location of steel contact but has not reached the outside surface of the concrete.

anodes and cathodes are separated by distances of one or more feet. The corrosion products of the steel apparently cause the cracking and spalling of the concrete. Indirect evidence that the corrosion products cause the concrete to crack is shown on Figure 3. Obviously the cracking or spalling of the concrete results from pressures exerted by the iron oxide products accumulating about the steel.

Corrosion tests were performed on a second reinforcing concrete pile of recent construction approximately 1½ years old. This pile, designated Pile B, was located approximately 200 feet south of the west end of the bridge and was in the tidal water zone.

There had been no cracking or spalling of the concrete in this pile. The pile had the original wooden driving cushion attached to the head of the pile.

The equipotential contours of Pile B indicated that an anodic area was located within the wooden driving cushion, and that the cathodic area was located approximately 6 feet distant and centered in the area of the concrete-imbedded steel. The maximum potential difference between the anodes and cathodes on the surface of the concrete was approximately 0.50 volt.

Loss of Metal

When the wooden driving cushion was removed, it was disclosed that some of the 1 inch diameter reinforcing steel bars within the wooden driving cushion had lost up to one-half of their original metal.

The steel which extended outside the driving cushion was badly rusted. In this area the corrosion attack was due to the atmosphere and an alternating sea water immersion, but the metal loss was not excessive. This rust was the typical stratified flake type, accompanied with the usual sea water organisms found on steel in a marine environment.

A limited experiment was performed on Pile B. First a potential survey was again made on the top face of this pile with most of the wooden driving cushion removed. The potential measurements indicated that the anodic surface potentials which originally were quite pronounced had decreased in the area where the wooden driving cushion had existed, but that the cathodic area had remained in the center of the pile.

Then a steel bar was placed in sodium chloride on top of the reinforced concrete pile in the previously cathodic area and electrically connected to the reinforcing steel within the pile. A surface potential survey was again made of this pile. Anodic potentials were then found in the areas that were previously cathodic, and cathodic potentials were measured in previously noncathodic areas. The steel bar had become an artificial anode with a maximum potential difference between anode and cathode of approximately 0.50 volt.

The surface potentials on this pile were obtained by three different "grounding" methods. In Method No. 1 a reference half cell was placed on the earth at a remote distance from the pile. In Method No. 2, the reference half cell was placed on top of the pile. The third method was to electrically connect to the reinforcing steel within the pile. In all methods of "grounding," the surface potentials on the pile were obtained with a half cell.

In each method of measurement, the surface potential differences or gradients on the pile correlated.

Specific Electrical Resistance of Concrete

Although laboratory means have been employed to measure the specific electrical resistance of concrete test samples, it was felt that the measurement of the electrical resistance of the concrete in place in the structure would eliminate many variables.

Four Electrode Method

The most practical means of measuring the resistivity of concrete appeared to be the four electrode method[2] which is commonly used in the geophysical and corrosion investigations of soils. As the average depth of the concrete cover over the corroding areas on the structure was 2 inches, the spacing of the contact points of the electrodes was limited to two inches. This was done so as to restrict the depth and effective volume of the measured concrete, thus minimizing the conduction effect that any reinforcing steel would have on the measurements.

In correlating the various resistivity measurements

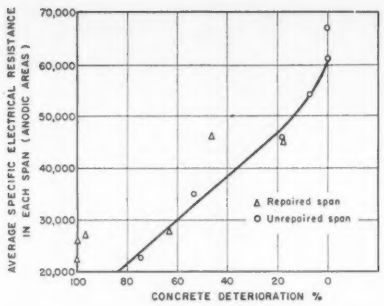

Figure 4—Specific electrical resistance in OHM-CM plotted against concrete deterioration.

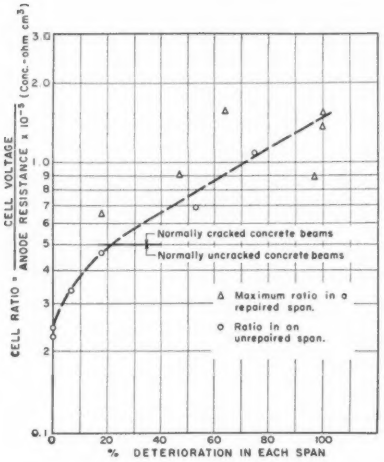

Figure 5—Corrosion cell ratio plotted against concrete deterioration.

over the entire span to the deterioration of the concrete in the anodic areas, it was found that measurements made in the cathodic areas did not necessarily indicate the condition of the concrete or steel in the anodic areas. However, by actual experience it was found that resistivity measurements made on the concrete in anodic areas gave in general a good indication of the degree of deterioration in these areas.

Correlation Between Resistivity and Concrete Deterioration

Figure 4 is a correlation between the resistivity of concrete at the anodic areas and deterioration of the concrete beams. Results obtained from twelve separate spans are shown. The average electrical resistance of the concrete in anodic areas was plotted against the actual deterioration of that span, wherein the percentage deterioration for each span was established by measuring the length of concrete beams which had cracked in each span. The circled points are spans that have not been repaired with shotcrete. The triangular points indicate the spans which have been repaired with shotcrete. The curve was drawn through the more statistically correct points developed from the unrepaired spans.

The general trend of this plot shows definitely that as the resistivity of the concrete increases, the deterioration decreases. The electrical resistivity of the

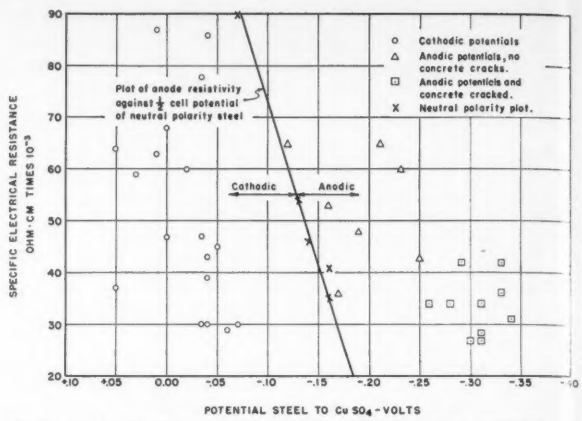

Figure 6—Half-cell potential of steel plotted against resistivity of concrete.

concrete at 0 percent deterioration, or where uncracked, appears to be in excess of 60,000 ohm-cm.

In the measurements of the potentials and resistivities of the concrete on the structure two factors became apparent: (1) the greater the potential differences between the anodes and the cathodes the greater the probability of severe corrosion, and (2) the lower the electrical resistance of the concrete, then again the greater the probability of corrosion attack.

Corrosion Cell Ratio

Figure 5 is a plot of the corrosion cell ratio in each span as correlated to the deterioration in that span. The corrosion cell ratio in this instance is defined as the ratio of the maximum surface potential difference in volts measured on the surface of the concrete between the anodes and cathodes in the deck and beams of a span as compared to the average specific electrical resistance of the concrete in ohm-cm in the anodic areas. The cell ratio was arbitrarily multiplied by 100,000 for ease in calculations.

The plotted points in this chart also are separated into repaired and unrepaired categories. Since it is statistically apparent that a corrosion cell could be altered by changing the environment, in this case by the removal of the original concrete and replacement of shotcrete, the curve was drawn through the more significant ratio points of unrepaired spans. Because this curve was established by tabulating data from all the corrosion cells found in the deck and beams of the investigated spans, the shape of the curve could be considered as representative of an average corrosion cell. However, the numerical values to the ordinates of this curve can only be expected to be representative of a number of corrosion cells in a single span. A distribution tabulation was then developed to correlate whether cracking or spalling would appear at a particular corrosion cell ratio. This distribution analysis did not employ average figures, but was based on tabulations derived from all of the individual corrosion cells. The results of this analysis indicated that if the cell ratio is greater than 0.5×10^{-5}, then as shown on Figure 5 the concrete is likely to be cracked or spalling at the anodic area, but if less than this value then cracking rarely appears.

Resistivity and Potential of Steel

Since there have been thermodynamic equations calculated[3] and plotted showing the corroding and non-corroding potentials of iron in solutions of different pH values, it was decided to determine whether or not a plot of the existing potentials of steel in concrete would correlate to the resistivity of the concrete.

In preparing trial plots of potential against resistivity, little correlation was obtained for the potential of steel either in anodic or cathodic areas against resistivity. Statistical correlations of potentials to resistivity were not made. However, a correlation was obtained when the neutral potential of the steel was plotted against the resistivity of the concrete in the anodic area.

The neutral potential of the steel was determined by the shape of the contours in a particular span. For instance, if a potential contour closed about a cathode, it was a cathode-influenced potential, and vice versa for a potential contour closing about an anode. The neutral potential is that potential of steel influenced by contours of neither anodic nor cathodic polarity. The neutral potential also has been described as the couple potential.[4]

Figure 6 is a plot of the neutral half cell potential of steel as correlated to the average resistivity of concrete in the anodic areas. The actual points for plotting this neutral potential curve are shown by the "X" points. There were only five spans which were measured for steel to $CuSO_4$ relationships, and these are included in this plot. As a check for this curve, the potentials of steel to a copper sulfate reference cell for all the anodes and cathodes in these spans were plotted against the electrical resistance of the concrete.

This chart may give an indication of the required potentials needed for steel when placed under cathodic protection. This chart also indicates the probability of galvanic corrosion of steel when imbedded in concrete of variable resistivity. The steel imbedded in concrete of lower electrical resistivity may be anodic to steel in concrete of higher electrical resistivity. An indication of this is borne out by the measured electrical resistivity of the concrete at anodic and cathodic areas. The average electrical resistivity of the concrete measured in cathodic areas was 64,000 ohm-cm and at the anodic areas 42,000 ohm-cm. The average electrical resistivity of old shotcrete on the structure is 60,000 ohm-cm. The resistivity of relatively newly placed shotcrete has been measured at 150,000 ohm-cm.

Observations

Thus far the predominate corrosion problems on the bridge have been concentrated above the lower tidal water plane. Insofar as the corrosion of the reinforcing steel is macro-galvanic, it may be possible that a secondary type of corrosion cell is created by differential aeration.

The present form of attack suggests that either the effective concentration of sea salts in the concrete is greater by evaporation above the water line than below it, or that a high but constant moisture content of the immersed piles inhibits the formation of active cathodes. Otherwise, extensive corrosion of the reinforced concrete piles should be prevalent below the low tidal water line. Apparently, the concentration of sea salts in the concrete above the tidal water could be the result of the continual condensation and evaporation of the sea water or spray on the surface of the concrete, and the transportation of these salts into permeable concrete by capillary attraction or other means.

The resistivity and the corrosion cell ratio charts indicate that the resistivity of the concrete decreases as the deterioration of the concrete increases. The exact mechanism or reason for this apparent drop in the electrical resistance of the concrete needs further study. This mechanism appears to be a combination of one or more of three suggested possibilities: (1) the previous mentioned continual accumulation of sea salts by condensation and evaporation of the sea water, (2) the current density of the existing corrosion cells causing the additional concentration of certain ions, such as chlorides, about the anodic area, or (3) by an increase in the moisture content of the concrete.

Cathodic Protection

Because of the widespread attack on the bridge, cathodic protection has been suggested as one means of curbing corrosion. In studies on the effect of EMF's ranging from 15 to 200 volts as applying to the bond strength of cathodic steel in concrete, numerous investigators[5,6,7,8] have observed a loss of the concrete bond when sodium chloride is present in the concrete. The investigators attribute the loss of the bond strength to the migration of alkali ions to the cathode electrode. These previous studies indicate that extreme care must be exercised should cathodic protection be applied to reinforcing steel in a "permanent" concrete structure.

A review of the literature indicates that a great deal of basic corrosion research remains to be done in the field of preventive corrosion of reinforcing steel. All data available indicate that in new installations in salt water environments, much future difficulty can be reduced by using a concrete formulation having minimum porosity and by a design having a maximum protective coverage of concrete over the reinforcing steel.

Conclusions

The potential measurements on the surface of a concrete bridge indicate that the corrosion of the reinforcing steel is the result of macro-galvanic corrosion.

The lower resistivity measurements of the concrete in the anodic areas indicate that the anodic areas may be created by a combination of one of two possibilities: (1) the moisture content of the concrete is greater in the anodic areas, or (2) the sea salt content of the concrete in the anodic areas is greater.

Because the corrosion of the reinforcing steel in this structure appears to be macro-galvanic corrosion, the repairing of the reinforcing steel and the subsequent application of shotcrete cover over the steel offers no assurance that further corrosion of the

reinforcing steel in another location will not take place in a repaired span. It therefore appears worth while that a reliable method to protect the reinforcing steel cathodically be developed.

Acknowledgments

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Any discussion of this article not published above will appear in the June, 1957 issue.

The Evaluation of Cooling Tower Corrosion Inhibitors*

By W. L. DENMAN and CHARLES B. FRIEDMAN

Introduction

GREATER WATER demands, lower water tables, and general difficulties in obtaining adequate quantities of cooling water have increased usage of recirculating cooling towers. Consequently, water conditioning problems of scaling, biological growth control, wood deterioration, and corrosion related to cooling tower operation have assumed major importance. Publications by Langelier,[1] Powell,[2] Applebaum,[3] Nordell,[4] and Palmer[5] are pertinent. The use of automatic controls on a field operated tower is described by Segraves.[6] An excellent summary of cooling tower problems appears in the 1952 Proceedings of the Thirteenth Annual Water Conference, Engineers Society of Western Pennsylvania.

In most areas, control of scale deposition requires operation at fairly low pH values which increases problems of corrosion control. Slightly soluble carbonates are converted to soluble sulfates by the addition of dilute sulfuric acid, to control scale deposits. Continuous blowdown is used to prevent sulfate scaling.

Use is made of inorganic inhibitors in various methods of corrosion control. They are used singly and in combination,[5,7,8] sometimes supplemented by organic synergists. Even though inorganic inhibitors, properly applied and controlled, are effective in corrosion control, they sometimes represent appreciable operating costs. In addition they often introduce problems of waste disposal. For these reasons it was important to find inhibitors or combinations which function at lower dosages and cost, or which control both deposition and biological growth without introducing disposal problems.

Acceptable laboratory corrosion test methods must produce results in a relatively short period which are comparable with long term field experience. Many different test units have been employed to study cooling tower problems and to devise solutions. Stone[8] used a circulating system with NDHA coil test units to determine corrosion rates, and test nipples to study pitting tendencies. Stone also employed electrical measurements involving time-potential curves to demonstrate corrosive tendencies. Powell[2] used a pilot cooling tower with recirculating water at 20 gallons per minute. Test nipples ¾-inch x 6-inch were coupled together in a jacket; steam passes through the inside of the nipples, and cooling water on the outside, permitting study of scaling and corrosive tendencies. Test coupons in glass jars permitted visual observations.

For preliminary work the authors assembled a simple recirculating device including a Pyrex vessel in which multiple metal coupons were suspended by glass hooks and totally immersed in water. Aeration was provided and the temperature raised to 140 F by cascading the water over a rotating, steam heated, stainless steel cylinder. This method exposed coupons

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Abstract

A small commercial cooling tower, equipped with control instruments, was installed in the laboratory for studying corrosion problems. In this tower the pH of the recirculating water was rigidly controlled automatically, and test coupons, nipples, and NDHA coil type units were used simultaneously to determine corrosion rates. Initial data revealed reasonably good correlation between corrosion rate measurements using all three types of corrosion test specimens. Inorganic corrosion inhibitors such as chromates, polyphosphates, and combinations of the two, when used in the experimental tower, provided corrosion protection comparable to that found in the field with those inhibitors. Therefore, it may be assumed that corrosion inhibitors which are successful in the experimental tower will be equally effective in field operations.

It was apparent that corrosion inhibitors such as polyphosphates must be fed in larger dosage than were required residually in the cooling water, to adequately protect against corrosion. Under operation conditions of the experimental tower, three or four times the calculated quantity of polyphosphate was required in order to maintain the desired residual dosage in the tower water.

Operating data from several inhibitor runs are reported and compared with observed corrosion rates in untreated (blank) runs. **2.3.4**

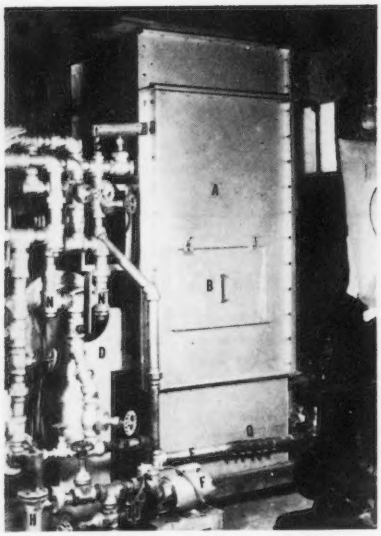

Figure 1—Pilot tower and auxiliary piping. Code to letters is as follows: A—cooling tower, B—door to interior of tower, C—exhaust duct, D—blower, E—pipe line carrying cooled water from tower, F—recirculating pump, H—pH flow assembly, N—holders for coil testers at 90 F, and Q—nipples at 90 F.

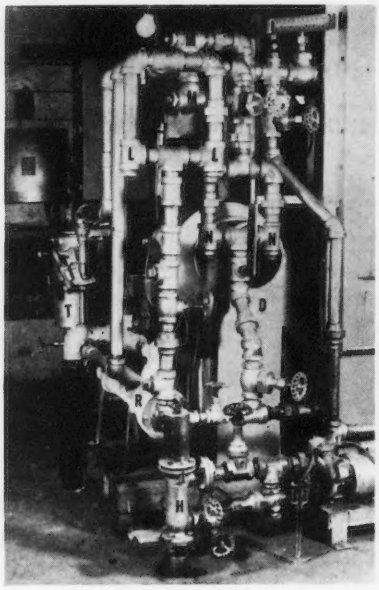

Figure 2—Corrosion specimen locations in pilot tower. Code to letters is as follows: D—blower, H—pH flow assembly, L—holders for coil testers at 170 F, M—holders for coil testers at 110 F, N—holders for coil testers at 90 F, R—heat exchanger, and U—coupon and holder.

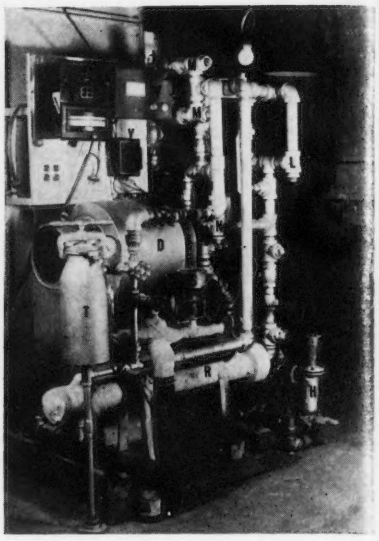

Figure 3—Pilot tower control instruments. Code to letters is as follows: D—blower, H—pH flow assembly, L—holders for coil testers at 170 F, M—holders for coil testers at 110 F, N—holders for coil testers at 90 F, R—heat exchanger, S—steam regulator, T—coupon corrosion chamber, V—nipples at 110 F, W—pH meter, X—indicator controller, Y—Solubridge for measuring dissolved solids, Z—Solubridge electrode holder.

for relatively short periods and thus measured the higher initial corrosion rates; even so, the degree of corrosion protection afforded by potential inhibitors was indicated. Materials which showed promise in this apparatus also provided corrosion protection in the experimental cooling tower described later.

It was felt, however, that a satisfactory method for evaluating cooling tower corrosion inhibitors should duplicate field operating conditions more closely. To accomplish this objective, a small commercial cooling tower, equipped with control instruments and auxiliaries, was installed for laboratory study. This pilot tower operated on automatic pH control; chemical application and blowdown were effected by positive displacement pumps.

Description of Equipment

Figures 1-5 show the cooling tower and auxiliary equipment. The tower is constructed of steel, internally coated. Tower internals are accessible through a door.

Air was forced through the tower at the rate of about 1800 cubic feet per minute. Air leaving the tower was discharged into the atmosphere through a duct. Cooling water was circulated at 13 gallons per minute by an all bronze pump, leaving the tower at about 90 F, passing through a pH flow assembly, and a Solubridge cell.

Flow of tower water was divided into two streams, one entering the heat exchanger and one by-passing it. In the heat exchanger the water was heated to 170 F with temperature control provided by a steam regulator. Heated effluent was combined with the by-passed water reducing the temperature to approximately 110 F and then flowed through a cylindrical chamber containing coupons. From the coupon chamber the water passed through removable test nipples, over coil testers, and was then sprayed into the cooling tower. Water entered the tower at about 110 F and was cooled about 20 degrees F. The location of corrosion specimens in the tower (refer to Figures 1, 2 and 3) and exposure temperatures are given below:

90 F—Steel nipples Q and Coil testers N

110 F—Coupons U, Steel nipples V and Coil testers M

170 F—Coil testers L

Rates of flow over the specimens are:

Coupons	—0.2 ft/sec
Nipples	—2.4 ft/sec
Coils	—1.2 ft/sec

Total dissolved solids are indicated on the Solubridge, which measures the conductivity of recirculating water; dissolved solids level is controlled by a blowdown pump.

Automatic pH control of cooling water is effected by pumping dilute sulfuric acid under electronic control. A Beckman Model W pH meter, operating from a glass electrode (located in the pH flow assembly), and connected to a Bristol indicator-controller, activates the acid feed pump. pH of cooling water is controlled to ±0.1 pH units.

Corrosion inhibitor feed solutions are stored in a stainless steel container, and fed continuously into the cooling tower by a positive displacement pump.

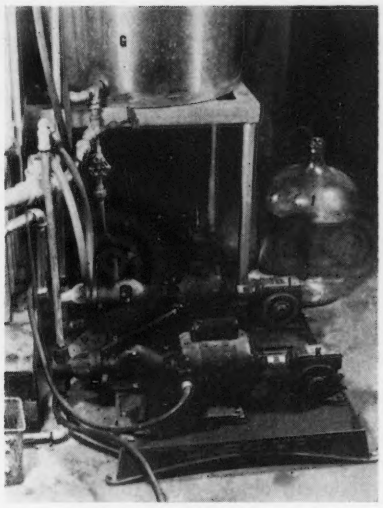

Figure 4—Chemical feed and blowdown equipment. Code to letters is as follows: G—treatment tank, I—acid reservoir bottle, J—chemical treatment pump, K—blowdown pump, O—acid feed pump.

Makeup water feed and tower water level is controlled by a float valve.

Whenever corrosion studies are contemplated, the question of the most suitable test specimen for the particular problem arises. Many corrosion engineers prefer coupons, some recommend coil testers and others advocate the use of nipples. Still other groups feel that corrosion rate data are more accurately obtained by electrical measurements.

Do commonly employed corrosion specimens (i.e., coupons, nipples and coil testers) of the same composition under the same test conditions furnish comparable data? To answer this question, cooling tower auxiliary piping was designed to accommodate test coupons, test nipples, and ASTM-NDHA corrosion testers (referred to hereafter as coil testers) for simultaneous corrosion rate measurements in a single test run.

Test Conditions

Calcium bicarbonate, common constituent of natural waters, is converted to slightly soluble carbonate in recirculating cooling tower operation. It is common practice to change carbonate to more soluble sulfate by addition of sulfuric acid, to prevent scaling. It is equally important to prevent deposition of sulfate scale. In the work described total dissolved solids concentration was controlled to maintain calcium sulfate at 1500 ppm or less, preventing sulfate scale formation even at 170 F.

The selection of cooling tower water pH range is very important. Based on field experience and literature study, an initial pH range of 6.0 to 7.0 was selected. For all tests discussed in this paper, a pH of 6.5 ± 0.1 was maintained. Lake Michigan water adjusted to this pH caused little or no scaling and wood deterioration through delignification was not expected. Table 1 compares an average analysis of

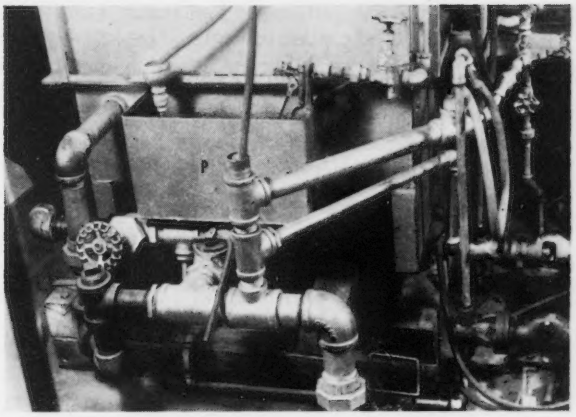

Figure 5—Pilot tower makeup water trough. The letter P on the photograph marks the makeup water trough.

TABLE 1—Typical Analysis of Water Used

	Sodium Polyphosphate Run 150 ppm	Chicago Tap Lake Michigan ppm
Total dissolved solids	1350	230
Silica as SiO_2	11	2
Iron as Fe_2O_3	0.75	0.2
Calcium as Ca	188	36
Magnesium as Mg	66	10
Sodium and Potassium as Na	122	7
Bicarbonate as HCO_3	29	144
Sulfate as SO_4	792	18
Nitrate as NO_3	11	Trace
Phosphate, ortho, as PO_4	31	...
Phosphate, poly, as PO_4	43	...
Chloride as Cl	57	6
Phenolphthalein alkalinity as $CaCO_3$	None	None
Methyl orange alkalinity as $CaCO_3$	24	118
Hardness as $CaCO_3$	740	130
pH	6.5	8.0

LANGELIER INDEX

Raw	During Test
+0.6	90 F = —1.2
+0.7	110 F = —1.1
+1.2	170 F = —0.6

Chicago city water with the composition of tower water during a typical test run.

Experimental Procedure

Operation of Cooling Tower

1. The cooling tower was prepared for a test run by recirculating untreated, hot tap water for two to three days to ensure complete removal of residual chemicals. The tower was operated in the usual manner except that neither acid nor treatment were fed: the blowdown rate was accelerated to change water 50 or 60 times during the cleaning period.

2. Weighed coupons were hung on glass hooks in the cylindrical coupon chamber. Weighed steel nipples and NDHA coil units were installed.

3. Tap water was run into the tower and sulfuric acid added to bring pH to the desired level. Treatment was added for

the initial 30 gallons of tap water (total capacity of the pilot tower).

4. The circulating pump was started.
5. The pH meter was standardized and the indicator-controller set to feed acid into the tower automatically as needed.
6. The heat exchanger and blower were put into service.
7. The tower operated in this manner for about 16 hours, until total dissolved solids were built up to about 1500 ppm. Blowdown and chemical feed pumps were then put into service to maintain desired solids and inhibitor levels.
8. Generally a test run proceeds for 10 days. Coupons were removed in duplicate every day, or as frequently as desired. The duplicate sets of steel nipples and coil testers were removed at the end of the run.

Corrosion Test Specimens

SAE 1025 and SAE 1009, 1-inch x 2-inch x 0.032-inch cold rolled steel coupons were used in these tests, with SAE 1010 steel coils, and 3-inch lengths of 1.75-inch OD, SAE 1015 seamless steel tubing.

Preparation of Corrosion Specimens

Polished Coupons—$\frac{3}{16}$-inch holes were drilled at each end of 1-inch x 2-inch mild steel coupons so they could be supported firmly by glass hooks in the corrosion chamber. Burrs were removed and all edges rounded with a belt sander. Coupons were then polished with an air-driven A222 SR6 rubber abrasive wheel (Chicago Wheel and Manufacturing Co.). The wheel used for polishing steel specimens must be reserved for this use only. After polishing, coupons were given a benzol wash followed by thorough drying with a clean cloth. Prepared coupons were stored in a desiccator above calcium chloride. After weighing, the coupons were ready for use in the cooling water test runs.

Sand Blasted Coupons—The same type of coupon was used as above. After deburring and rounding edges, the coupons were sandblasted, then rinsed in benzol and dried. Prior to use the coupons were etched in 1-3 CP hydrochloric acid for 15 minutes, rinsed in distilled water until free of acid, dipped in isopropyl alcohol and benzol, and air dried. The specimens were aged for a minimum of one day in a desiccator and weighed just prior to use.

NDHA Coils—The SAE 1010 coils were rinsed in benzol, and dried. They were then etched for 15 seconds in 180 F, 1-3 CP hydrochloric acid, followed by rinsing with distilled water until free of acid. The coils were then dipped in isopropyl alcohol, immersed in benzol, dried, and stored in a desiccator. After weighing, the coils were assembled on NDHA Coil Testers, ready for installation in tower piping.

Steel Nipples—Seamless 1¼-inch OD SAE 1015 seamless steel tubing, made from a single heat, was purchased in large quantity so that several years supply would be available. Three-inch sections of the tubing were cut, burrs removed, and the outside rough polished on a belt sander. The nipples were rinsed in benzol, dried, etched in 1-3 CP hydrochloric acid for 15 minutes. They were then neutralized, rinsed in isopropyl alcohol, dipped in benzol, dried, and stored in a desiccator. After the nipples were weighed they were coated on the outside with an alkyd resin; the resin coating was dried at about 140 F.

Removal of Corrosion Products from Specimens After Test

Coupons—Both polished and sandblasted coupons were cleaned in the following manner:

1. Corroded test coupons were removed from the coupon chamber, scrubbed in flowing tap water to remove adherent corrosion deposits, dipped in isopropyl alcohol, followed by a benzol rinse, and then dried.
2. The coupons then were immersed in inhibited, concentrated, hydrochloric acid for 30 seconds at room temperature, with agitation.
3. Specimens were removed from the acid and immediately dipped in concentrated sodium carbonate to neutralize residual acid.
4. Coupons were rinsed with distilled water, followed by dips in isopropyl alcohol, and benzol, then wiped with a clean cloth, stored in a desiccator and weighed. If coupons are not entirely free of corrosion products, the procedure from Step 2 on is repeated, before weighing.

NDHA Coils—The steel coils were cleaned in the same manner as above, except that neutralization was replaced by repeated distilled water rinses.

Steel Nipples—The external protective coating was removed in a hot, 10 percent caustic solution. The nipple was then rinsed and subjected to the cleaning procedure outlined above for coupons.

All specimens were weighed on an analytical balance, weight losses determined, and corrosion rates calculated. Coupons and steel nipples were examined carefully before and after removal of corrosion products; frequency and severity of pitting were studied and recorded.

Experimental Program

The objectives of the present work were to: (1) Calibrate the pilot tower, (2) Establish reproducibility of data, (3) Correlate corrosion rates obtained with various types of test specimens, (4) Determine feed dosages required to maintain given chromate or polyphosphate levels, (5) Measure temperature coefficients of corrosion within the conditions of the pilot tower, and (6) Compare known and new compounds as cooling tower corrosion inhibitors.

Calibration of Pilot Tower

The pilot tower was calibrated without corrosion inhibitors, and then with chromates, polyphosphates, and combinations of the two. Representative data are given in Tables 2-5. These data establish corrosion rates under standard conditions, and permit evaluation of materials as potential cooling tower corrosion inhibitors.

Reproducibility of Data

Tables 2 and 3 give representative replicate data of corrosion rates. In general, agreement was good.

Correlation of Corrosion Rates With Various Types of Test Specimens

Three types of corrosion test specimens were evaluated in simultaneous measurements. Representative data are given in Tables 2, 3, 4 and 5 and a comparative summary is given in Table 6. Table 2 indicates that equivalent corrosion rates are recorded with polished or sandblasted coupons under blank conditions (no corrosion inhibitor present). Tables 3, 4, 5 and 6 show the correlation which exists between inhibited corrosion rate measurements using steel coupons, steel nipples and steel coil testers. In general, steel nipples and coil testers showed slightly higher corrosion rates than did steel coupons when exposed under identical conditions (except for velocity.

Feed Dosages Required to Maintain Given Chromate or Polyphosphate Levels

At the present time chromates and/or polyphosphates are employed as cooling tower corrosion inhibitors more frequently than other inhibitors. Yet there are little published data to indicate polyphosphate dosage required to provide a desired residual level. Fortunately more information is available concerning chromates. Typical dosages fed and residuals maintained in the pilot tower under test conditions previously described, are given in Table 7. Initial chemical dosages were as follows:

Polyphosphate—Four times the desired maintained concentration.

Chromate—Twice the desired operating concentration.

Tests indicated a high rate of reversion from polyphosphate to orthophosphate in the recirculating system. It was necessary, generally, to continue feeding four times the polyphosphate quantity desired residually. In contrast, chromate levels were readily maintained by feeding the calculated dosage (after the initial slug treatment).

Temperature Coefficient of Corrosion

Chemical kinetics teaches that reaction rates approximately double for a 10 degree C rise in temperature. In general, this also holds true for corrosion processes. Representative data on the temperature coefficient of corrosion are given in Table 8. In every case a temperature coefficient of 1.5 or less was obtained from a 11 degree C rise in temperature.

Evaluation of Several Known Cooling Tower Corrosion Inhibitors

Table 6 summarizes comparative data on several cooling tower inhibitors. Chromates or polyphosphates alone, and combinations of chromates and polyphosphates gave satisfactory corrosion inhibition. Since chromates and/or polyphosphates in the pilot tower provide corrosion inhibition comparable to that found in the field, it may be assumed that corrosion inhibitors providing satisfactory protec-

TABLE 2—Corrosion Rates With No Inhibitor

SPECIMENS	Temperature	Days Exposed	MPY	Average MPY
SAE 1009 Polished steel coupons	110 F	1	53, 47	50
	110 F	4	40, 40	40
	110 F	10	36, 32	34
SAE 1009 Sandblasted coupons	110 F	1	58, 63	61
	110 F	4	48, 43	46
	110 F	10	38, 34	36
SAE 1010 Steel coils	110 F	10	32, 33, 28, 26, 30, 35	31
	170 F	10	52, 52, 54, 50, 54	52
	90 F	10	19, 20, 20, 20, 21, 22	21
SAE 1015 Steel nipples	90 F	10	22, 24	23
	110 F	10	32, 38	35

TABLE 3—Corrosion Rates Obtained Using Fed Dosage of 190 PPM Sodium Chromate

SPECIMENS	Temperature	Days Exposed	MPY	Average MPY
Polished coupons	110 F	1	3.3, 2.8	3.0
	110 F	5	1.3, 1.3	1.3
	110 F	9	0.6, 0.6, 0.7, 0.6	0.6
Steel nipples	110 F	9	3.5, 4.2	3.8
	90 F	9	3.1, 3.1	3.1
Steel coils	170 F	9	5, 5, 5, 5, 5, 6	5
	110 F	9	2, 2, 2, 1, 2, 2	2
	90 F	9	2, 2, 2, 2, 2, 2	2

TABLE 4—Corrosion Rates Obtained Using Fed Dosage of 150 PPM Sodium Polyphosphate

SPECIMENS	Temperature	Days Exposed	Average MPY
Polished steel coupons	110 F	1	2.3
	110 F	4	1.3
	110 F	10	0.9
Steel nipples	110 F	10	1.7
	90 F	10	1.3
Steel coils	170 F	10	0.8
	110 F	10	1.3
	90 F	10	1.5

TABLE 5—Corrosion Rates Obtained Using Fed Dosages of 60 PPM Sodium Polyphosphate and 20 PPM Sodium Chromate

SPECIMENS	Temperature	Days Exposed	Average MPY
Polished steel coupons	110 F	1	1.5
	110 F	3	0.8
	110 F	10	0.6
Steel nipples	110 F	10	1.4
	90 F	10	1.0
Steel coils	170 F	10	1.7
	110 F	10	1.2
	90 F	10	0.8

TABLE 6—Comparative Data Obtained By Use of Coupons, Steel Nipples, and Coils After 10 Days Exposure

Treatment—Dosage Fed	CORROSION RATES (In MPY)					
	Coupons 110 F	Coils 90 F	Coils 110 F	Coils 170 F	Steel Nipples 90 F	Steel Nipples 110 F
No Inhibitor	37	20	31	53	23	35
Sodium Chromate 190 ppm[1]	0.6	2	2	3.5	3	3.5
Sodium Chromate 50 ppm[1]	0.8	0.7	0.9	1.9	1.6	2.3
Sodium Polyphosphate 150 ppm	0.9	1.5	1.3	0.8	1.3	1.7
Sodium Polyphosphate—Sodium Chromate						
10 ppm 50 ppm	1.1	0.4	0.6	3.5	1.5	1.8
40 ppm 40 ppm	1	2.7	1	2.7	1	1
60 ppm 20 ppm	0.6	0.8	1.2	1.7	1.0	1.4
Sodium Polyphosphate—30 ppm Sodium Chromate 5 ppm Zn^{++} 20 ppm	0.7	0.5	0.6	7.5	1.0	1.3

Note: These figures are averages of duplicate specimens for coupons and nipples. Coil data are the average of results obtained from six coils.

[1] Frequency and severity pitting studies given in Table 10 shows that 50 ppm sodium chromate provides less corrosion inhibition than 190 ppm. The figures in the above table appear to show the opposite to be true. Actually the data from the two tests are of about the same magnitude on a weight loss basis, and are within the limits of experimental error expected in tests of this type.

TABLE 7—Fed and Maintained Concentrations

INHIBITOR (s)	Average Concentration In PPM	
	Fed	Maintained
Sodium Polyphosphate	150	33
Sodium Chromate	50	50
Sodium Polyphosphate	10	3
Sodium Chromate	50	33
Sodium Polyphosphate	40	10
Sodium Chromate	40	36
Sodium Polyphosphate	60	19.5
Sodium Chromate	20	20

Note: All concentrations are expressed as the sodium salts of polyphosphate or chromate as the case may be.

TABLE 8—Corrosion Rate Temperature Coefficients for a Rise in Temperature of Approximately 11 Degrees C

Treatment—Dosage Fed	Temperature Coefficients Between 90 F—110 F	
	Coils	Nipples
No Inhibitor	1.55	1.52
Sodium Chromate—190 ppm	1	1.13
50 ppm	1.29	1.44
Sodium Polyphosphate—150 ppm	0.87	1.31
Sodium Polyphosphate—Sodium Chromate		
10 ppm 50 ppm	1.5	1.2
60 ppm 40 ppm	1.2	1.4
Sodium Polyphosphate—30 ppm Sodium Chromate — 5 ppm Zn^{++} —20 ppm	1.2	1.3

TABLE 9—Corrosion Rates Obtained Using Dimetallic Type Glassy Phosphates on Sandblasted SAE 1009 Coupons at 110 F

Days Exposed	Average MPY
1	5.4
3	2.9
9	2.1

Note: Fed 50 ppm, and maintained an average of 38 ppm.

tion in the pilot tower will also serve effectively in larger, similarily operated cooling towers.

Dimetallic glassy phosphates have been studied in the pilot tower and data from one run are given in Table 9. At 50 ppm dosage, very good corrosion inhibition was obtained, reversion to orthophosphate amounted to about 25 percent, and pitting was not evident. At 20 ppm dosage, corrosion inhibition was reduced, reversion to the orthophosphate amounted to about 50 percent and pitting was quite noticeable.

Pitting Studies

Corrosion inhibitors which are efficient on a weight loss basis sometimes do more harm than good because they promote localized corrosion, and/or pitting. Pitting is more destructive than uniform corrosion because it causes leaks in piping and other equipment, necessitating early replacement. Supplementing corrosion rate data, pitting studies were made to further compare relative effectiveness of the various corrosion inhibitors tried.

Both macro and micro examinations of test specimens were made to determine the frequency and severity of pits. Table 10 shows that uniform corrosion occurs when no inhibitor is used. Of the corrosion inhibitors listed in the table, a combination of 40 ppm sodium polyphosphate and 40 ppm sodium chromate (applied dosage) furnished the best protection against pitting. When this combination was employed, there were few areas of localized action, and these areas existed as stains only.

Future Status of Cooling Tower Water Treatment

While chromate alone or in combination with polyphosphate and/or zinc gives good inhibition of corrosion, it suffers from toxicity handicaps. Such toxicity refers not only to the problems arising from use but also to problems resulting from disposal of blowdown, etc. In the future it may be anticipated that waste disposal requirements will be more rigid.

More efficient and less toxic corrosion inhibitors must be developed if the art of treating tower cooling water is to make progress. Corrosion inhibition is, however, only a part of the problem. It has been said that the present state or condition of tower cooling water treatment parallels that of boiler feed water treatment of some 25 years ago. To ensure progress in all phases of cooling system technology, tower manufacturers and water conditioning consultants, in cooperation with industrial cooling tower users, must embark upon a concerted, long range research program.

Any program leading to the development of more effective corrosion inhibitors may take the direction of not only inorganic versus organic products but also combinations of the two. Inorganic compounds are much more restricted in scope and properties than are organic compounds. Therefore, the program most likely to be successful may deal principally with organic compounds. Polar or semi-polar organic corrosion inhibitors are currently used in return condensate lines (filming amines), in downhole oil well treatment, in oil well flooding operations, in petro-

TABLE 10—Pitting Observations on Coupons Employed During Some of the Pilot Tower Test Runs

Treatment Fed	10 Day Corrosion Rate in mdd	PITTING	
		Frequency	Severity
1. None	200	Overall corrosion mostly; some local corrosion areas; uneven surfaces.	
2. Sodium Chromate—190 ppm	3.3 (9 days)	Average about 4 per coupon	Shallow, very small
3. Sodium Chromate—50 ppm	4.2	Average about 10 per coupon	Deeper, larger than above
4. Sodium Polyphosphate—150 ppm	5.0	High	Better than 3; worse than 6 or 7
5. Sodium Polyphosphate—Sodium Chromate			
10 ppm 50 ppm	5.9	Average about 15 per coupon	Severe
6. 40 ppm 40 ppm	6.0	Very low	Stains only
7. Sodium Polyphosphate—Sodium Chromate			
60 ppm 20 ppm	3.3	High	Stains only
8. Zn^{++}			
30 ppm 5 ppm	3.8	Better than 5	
20 ppm			
9. Imidazoline—type compound—200 ppm	69.6	Varied, but not high	Very Severe

leum refineries, in diesel cooling water and recently in cooling tower water (Oxford[9] and Russell[10]).

Evaluation of Organic Corrosion Inhibitors in Pilot Tower

Several potential organic cooling tower corrosion inhibitors were evaluated in the pilot tower. The organic compounds studied ranged from relatively simple water soluble materials to high molecular weight water dispersable products. The best organic inhibitor tested to date provided only about 70 percent inhibition.

It is believed that the surface has just been scratched in the testing and development of organic compounds as potential cooling tower corrosion inhibitors and that an outstanding cooling tower corrosion inhibitor, free of toxicity and reversion problems, will be derived from the vast field of organic chemistry.

Conclusions

It is felt that by use of a small, automatically controlled, commercial tower, reliable, useful results have been obtained. Furthermore, it appears that information acquired through use of this type of tower can be directly transferred to larger field operated towers.

Comparative corrosion specimen data obtained thus far show good agreement, indicating that specimens can be used on the basis of convenience, and upon the type of information desired. All corrosion specimens, when used correctly, appear to furnish reproducible data.

In order to maintain desired residual dosage levels when using polyphosphates in the experimental tower, it was necessary to feed about four times the calculated quantity; with chromates only normal calculated quantities generally were required.

Increased temperatures cause increased corrosion rates, but generally the temperature coefficient is not as high as chemical kinetics would indicate.

Succesful use of organic inhibitors in many highly corrosive systems indicates that the development of organic compounds for use in cooling towers is possible.

The importance of recirculating cooling tower water in modern industry is well recognized. Not only must tower water be properly treated to avoid the damaging effects of many natural waters, but treatment must also be instituted to permit re-use of cooling water because of the growing shortage of industrial water. During the past ten years much has been learned and accomplished in regard to treatment of cooling tower water but there are not satisfactory answers for many of the problems. Active long range research activities are the chief means by which proper treatments may be developed. Continued cooperation between corrosion engineers and water treatment concerns, and the efforts of organizations such as the NACE, in providing dissemination of progress made, will do much to speed up the overall program.

Acknowledgment

The authors express their appreciation to J. F. Wilkes, H. Kerst, and R. G. Dalbke for their assistance and advice during the research program, and in the preparation of this paper.

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Any discussion of this article not published above will appear in the June, 1957 issue.

Polyvinylidene Chloride Film and Microcrystalline Wax For Protecting Underground Pipe*

By TED KENNEDY, JR.

Introduction

NO MOISTURE—no electrolytic corrosion. On this basic point all corrosion experts agree. If a metal surface can be thoroughly and permanently wet with some material other than water, electrolytic corrosion cannot take place.

The design of pipe coatings and wrappers is essentially a materials problem. What materials will best isolate the pipe surface from contact with soil electrolytes?

A coating system of high quality microcrystalline wax applied without primer and wrapped with a polyvinylidene chloride film maintains with remarkable durability a continuous wetting of the pipe surface with a material other than water.

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Abstract

Six case histories are given of the use of polyvinylidene chloride film in conjuction with microcrystalline wax to protect underground pipes. It was found that microcrystalline wax of high quality appears to be a superior wetting agent and when wrapped with a protective film of polyvinylidene chloride will thoroughly and permanently protect a pipe surface from corrosion where properly applied. Although further information must be accumulated to substantiate fully the performance of these materials in the field, results to date indicate that these materials provide superior protection. 5.4.10

Microcrystalline Wax Properties

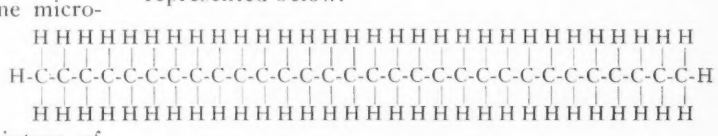
Microcrystalline wax film of high quality applied without primer is a superior "waterproofing" agent, suited for the task of thoroughly and permanently isolating the pipe surface from contact with soil electrolytes.

Generally speaking, microcrystalline wax is a homogeneous mixture of several different hydrocarbon molecules, principally normal-paraffins, isoparaffins and naphthenes. Their average molecular weight ranges from 580-700. The average number of carbon atoms per molecules ranges from 30-75. Represented by their chemical formula the paraffins present range from $C_{30}H_{62}$ to $C_{75}H_{152}$.

Many attempts have been made to define microcrystalline waxes in a brief statement. During World War II, the Petroleum Administration used the following description in its allocation order: "Microcrystalline wax is a solid hydrocarbon mixture of molecular weight averaging higher than paraffin wax, possessing plastic properties, separated entirely from that part of crude petroleum commonly designated as heavy lubricating and cylinder oil stocks, and having minimum kinematic viscosity of 5.75 centistokes at 210 F and a maximum penetration of 60 at 77 F determined by ASTM method D5-25."[1]

Ivanovsky[2] defines microcrystalline waxes as belonging to a "specific group of organic thermoplastics," and in so doing brings emphasis to the plastic nature of microcrystalline wax.

The structural formula for $C_{30}H_{62}$, a long chain hydrocarbon of the paraffin family, is graphically represented below.



In manufacture, microcrystalline wax is chilled and centrifuged from heavy lubricating stock and in a succession of steps is refined and blended to give the required melting point range. In the process of further refinement lighter molecular weight oils are sweated, pressed or further centrifuged from the wax itself along with any solvents or vapors that may be remaining. The final microcrystalline wax has a minute crystalline structure when viewed under a microscope of sufficient power, hence the name, "micro" crystalline (see Figure 1).

When the crystals of microcrystalline wax are examined in even greater detail it is seen that they are orthorhombic in structure. Crystals of $C_{30}H_{62}$, a component of microcrystalline wax, are illustrated in Figure 2 and here the orthorhombic structure is clearly shown.[3]

* Submitted for publication September 26, 1955. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Houston, Texas, October 18-21, 1955. This paper was preprinted under the title "The Use of Combined Polyvinylidene Chloride Film and Microcrystalline Wax for Protecting Underground Pipe from Corrosion."

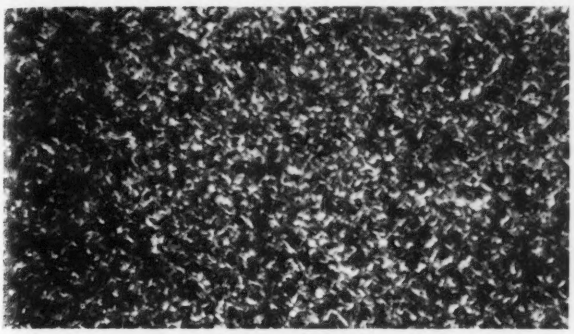


Figure 1—Photomicrograph of microcrystalline wax. Magnification 200 x with polarized light.

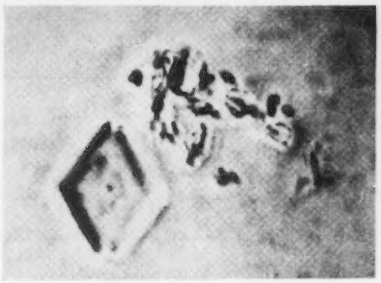


Figure 2—$C_{30}H_{62}$ from nitrobenzene (270 x). Typical orthorhombic crystals.

TABLE 1—Typical Physical Property Specifications of a Representative Wax

Melting point (ASTMD 127-49)	165-175 F
Viscosity, SSU at 210F (ASTMD 88-44)	75-100
Penetration, needle 100 gms 5 Sec. 77F (ASTMD 5-49)	28-32
Ash (ASTMD 482-41)	0.1-0.3
Specific gravity at 32 F	0.947
(ASTMD 70-27) at 77 F	0.928
(ASTM 287-39) at 170 F	0.816
at 250 F	0.789
Flash Point (ASTMD 92-45)	525 F min.
Fire point (ASTMD 92-45)	550 F min.
Inhibitors	Selected
Wetting agents	Selected

Microcrystalline wax may be tested by means of standard ASTM tests for determining properties of materials solid or highly viscous at normal temperatures, but with relatively low melting point. Table 1 tabulates the material properties of a representative wax specification blended from several waxes each with its own particular melting point. Such a blend provides the high temperature strength, and low temperature ductility required for pipe line application. In addition to standard ASTM tests certain special tests have been developed to explore further the fitness of materials to displace moisture completely and permanently from the metal surface.

The rheological properties of wax are such that a continuous, uniform coating can be applied. Wax heated to a liquid state has a very low surface tension[3] and this, together with the watery viscosity, makes it possible to get into tiny pores on the steel surface continuously wetting the surface and also increasing the bond. But probably more important is this ability to fill immediately all pores thus displacing all the air which otherwise would form blisters in the ambient heat.

Much valuable experience in the use of microcrystalline wax as a water-proofing agent may be found in the manufacture of wax paper for food packaging. Here an absolutely continuous film is a must. One pin-hole will utterly destroy the effectiveness of the entire package. Wax for the paper industry provides this film. One authority states, "since resistance to the passage of moisture vapor is the foremost property of microcrystalline wax, it is no wonder that the paper industry is its largest consumer."[4]

The food industry not only packages food in waxed paper, but is now preserving fruit, vegetables, and frozen meats directly in microcrystalline wax itself, "to preserve the juices."[5]

The Federal Government for much of its overseas packaging specifies a dip of microcrystalline wax followed by a wrap of plastic film repeated in one or more cycles. Automobile spare parts, including crank shafts, cylinder blocks, valves and countless other parts are prepared for long-time storage with a coating of microcrystalline wax.

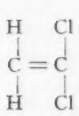
In the field of protection of underground pipe, microcrystalline wax has been used as a pipe coating material for 30 years or longer, and is still thoroughly protecting the pipe surface where the wax itself has been properly protected. However the wax itself, though inert and not subject to deterioration, does not have enough internal strength to withstand all soil pressures. For this reason designers of pipe protection who have selected microcrystalline wax as the primary surface wetting agent incorporate with the wax an external wrapper to serve as a barrier between wax and soil.

After extensive testing in both laboratory and field, one particular plastic, in film form, has been found to be particularly suitable for use with a microcrystalline wax. This plastic is polyvinylidene chloride.

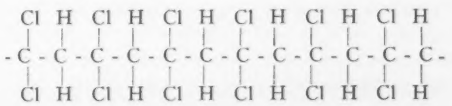
Polyvinylidene Chloride Properties

Polyvinylidene chloride has petroleum and brine for its basic raw materials. Ethylene from cracked petroleum and chlorine from the electrolysis of brine are combined to produce trichloroethane, which is converted to vinylidene chloride.

The formula assigned to the basic polyvinylidene chloride molecule or monomer is $CH_2{:}CCl_2$ and may be represented as follows:[6]



Many vinylidene chloride molecules are polymerized together to produce polyvinylidene chloride which can be represented diagrammatically in the following manner.



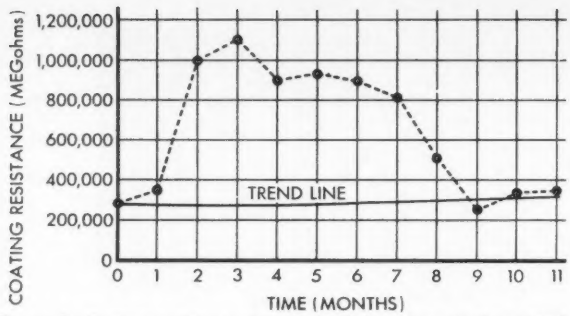


Figure 3—Coating resistance (average) of four test nipples coated with microcrystalline wax wrapped with polyvinylidene chloride film over an eleven month period.[7]

TABLE 2—Properties of Polyvinylidene Chloride Film

Gage in inches	0.002
Specific Gravity	1.68
Area Factor, Approx. Sq. in/lb.	8,150
Water Vapor Transmission gms/100 sq in/24 hrs at 100 F and 90 percent R. H.	0.20
Water Absorption	Negligible
Resistance to Heat—intermittent	Up to 200 F
Resistance to Heat—continuous	Up to 140 F
Resistance to Cold	Good Flexibility at 0 F
Tensile Strength lb/sq in.	7000-15000
Percent Elongation	20-40
Bursting Strength lb/sq in—Mullen	60
Tear Strength—gms Elmendorf	30-40
Dielectric Constant-	
10^2 Cycles	4.9-5.3
10^3 Cycles	3.9-4.5
10^5 Cycles	3.4-4.0
Percent Power Factor:	
10^2 Cycles	3.5-4.5
10^3 Cycles	5.2-6.3
10^5 Cycles	3.9-4.5
Breakdown Voltage Volts/Mil	3000-4500
Surface Resistivity—Ohms	10^{12}-10^{15}
Volume Resistivity—Ohms—Cms	10^{12}-10^{15}

TABLE 3—Resistance of Polyvinylidene Chloride Films to Various Chemicals at 25 C

Chemical	Resistance
Dilute Mineral Acids	Excellent
Concentrated Mineral Acid (except H_2SO_4 and HNO_3)	Excellent
Organic Acids	Excellent
Alkalies (except NH_4OH)	Good
Alcohols	Excellent
Aliphatic Hydrocarbons	Excellent
Oils, Fats and Waxes	Excellent
Pharmaceuticals and Detergents	Excellent

The properties of polyvinylidene chloride film are tabulated in Table 2.

In addition to the above listed properties, laboratory tests conducted on buried samples indicate that polyvinylidene chloride film is unaffected by soil bacteria. During World War II polyvinylidene chloride film was used for metal parts packaging and was unaffected by fungus growth under very adverse conditions.

Chemical inertness tests (Table 3) show that polyvinylidene chloride is completely inert to all chemicals commonly found in soils. Furthermore it is completely inert to crude petroleums and gasoline.

Selected Case Histories

A few case histories are submitted to document performance to date of combined microcrystalline wax and polyvinylidene chloride film in the laboratory and in the field.

Case History 1

On September 17, 1952, four 12-inch lengths of ¾-inch pipe coated with microcrystalline wax and wrapped with polyvinylidene chloride were buried in 10,000 ohm soil which had a pH of 6.0. The soil was kept moist by adding water each week.

Five-hundred volts EMF was placed across the pipe and soil. Current drain-off was periodically measured, and from this figure coating resistance was computed in megohms (see Figure 3).

Case History 2

Microcrystalline wax and polyvinylidene chloride film were applied to 19,246 feet of 8-inch line owned by the Union Gas Company of Canada, Limited, in Tilbury East Township. This line was laid by a contractor in 1951 in tiled hard clay soil. This 8-inch pipe had been used previously but had been reconditioned prior to the application of the coating over-the-ditch. The coating specification was as follows:

1/32-inch microcrystalline wax coating
2 mil polyvinylidene chloride wrapper

Physical examination of the coating and coating resistance tests were conducted last summer by a consulting corrosion engineer. To date, there appears to be no deterioration of the coating or wrapper and the wrapper lap is remaining firm. Sixteen 17-pound magnesium anodes are cathodically protecting this length of line with a total current output of 350 milliamperes. The average coating resistance was calculated to be 29,000 ohms/square foot.[8]

Case History 3

In August of 1950, the Michigan Gas Utilities Company in Monroe, Mich., coated and wrapped approximately five miles of 4-inch line pipe with microcrystalline wax and polyvinylidene chloride plastic film. The line was laid through a variety of soil including sand, clay and cinder fill to replace a badly deteriorated line that had not been coated or wrapped.

Because of the purpose and the location of this line it was decided to make use of it as a testing point as to the condition of the wrapper from time to time as new connections were being made.

During the summer of 1954 a relocation of approximately 1,500 feet of this line was necessary due to highway construction. This provided an excellent opportunity to observe the condition of the coating and wrapper.

The microcrystalline wax undercoating, and the polyvinylidene chloride film showed no deterioration. The film elasticity, color, surface smoothness, tensile strength and ductility appeared unchanged. The plastic film and wax coating were bonded together. The wax coating was itself bonded to the pipe at all points, including areas where the pipe had been severely bruised during the process of removing the line from the ground.

There was no evidence to indicate that either the coating or wrapper had changed from the condition in which it was put in the ground.

In the fall and winter of 1951, the same company also coated and wrapped approximately 22 miles of

10-inch and 44 miles of 8-inch line pipe with the same material. This line also was laid through a variety of soil including both sand and clay. Soil resistance varied from 1,500 ohms to more than 50,000 ohms. Temperature during construction varied between 80 F early in the fall, to 0 F later in the winter. The wax coating was applied directly to the pipe without a primer.

Since this line has been in operation, there have been numerous occasions to tap this line for the purpose of new laterals and service taps at varied locations. In each instance the coating and wrapping appeared to be in the same condition as previously mentioned.

Case History 4

The Dow Chemical Company has approximately 140 miles of brine transmission line coated and wrapped with microcrystalline wax and polyvinylidene chloride film. Most sections of these lines have been in service from three-to-four years. Over fifty percent of the total mileage handles raw brine at a temperature of 110-120 F. Although no attempt was made to insulate the brine transmission system from other underground metallic structures (i.e., well casings, plant piping at the line terminals, etc.), and most of the magnesium anodes are bonded directly to the line without current restricting devices, indications are that current requirements for a polarized pipe/soil potential of —0.90 to —1.10 volt (Cu/Cu-SO_4 reference) are very low.

Miscellaneous sections of the transmission system have been examined at several locations, including some five thousand feet of line which was removed from service (excavated), and at all points the wax/film system was in excellent condition. The wax was "live" and bonded perfectly to the pipe surface; the film retained its physical properties and remained nonwettable by the soil constituents. The coating system exhibited excellent resistance to soil stresses and deformation in heavy clay soils where these conditions are usually quite severe.[9]

Case History 5

During the spring and summer of 1953 approximately 20 miles of 24-inch line pipe was coated (Figure 4) with 1/32-inch microcrystalline wax coating, wrapped with a 2 mil film of polyvinylidene chloride and over-wrapped with 80 pound Kraft paper to serve as partial shield during lowering in and backfilling. During the spring of 1955 an exposure was made to examine the condition of the coating system.

As is shown in Figure 5, the Kraft paper has completely disappeared. The color, surface smoothness and flexibility remained unchanged, and there was no evidence of any other film deterioration. The film was cut and folded back to expose the wax undercoating. Again, as might be expected, there were no indications of any wax coating deterioration.

Case History 6

In the following paragraphs is a summary of the observations and tests made by a consulting engineer on these coating materials in the summer of 1954:

Figure 4—Twenty-four inch line pipe as originally coated with microcrystalline wax coating, polyvinylidene chloride film, and Kraft paper in 1953.

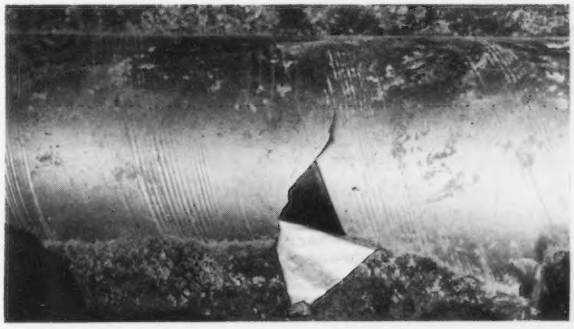


Figure 5—Line pictured in Figure 4 as exposed during the spring of 1955.

"For some days I watched the application of the material on a line of considerable size in New York State. No difficulty was being experienced by the applicators. Considerably fewer men are necessary in the coating crew than with the hot enamels. A holiday detector was being used although it is of doubtful value. Any skip or fault in the coating is easily detected with the eye. The coated pipe was being lowered directly into the ditch behind the coating machine. It was seldom necessary to stop the machine for the purpose of making repairs to the coating.

"This line was about fifty miles long. At present it is not possible to measure accurately the current requirements to protect cathodically the line due to connections with other lines. However, from the information obtainable it appears that the entire line is being protected with about three amperes.

"Two lines were examined in Canada and Michigan. The line in Canada was laid in a very heavy gumbo soil, the kind that punishes a coating very severely. The line had been laid for four years at that time. Bell holes were dug and the coating examined. There was no evidence of damage to the coating. The soil merely lays on the wrapper and does not cling to it.

"On the Michigan line it was possible to determine

the electrical resistance of the coating. One section of twelve inch pipe seven miles in length was being protected with one magnesium anode at one end. The resistance of the coating was 300,000 ohms per square foot of coating. Due to the nature of the material of this wrapper it is not probable that there will be any appreciable reduction in this coating resistance[12] for a great many years."[10]

Summary

The goal of pipe coatings and wrapping specialists should be to design coating and wrappings material that will thoroughly and permanently isolate the surface of underground pipe from contact with soil electrolytes.

Microcrystalline wax of high quality appears to be a superior wetting agent and when wrapped with a protective film of polyvinylidene chloride, will thoroughly and permanently protect the pipe surface from corrosion where properly applied.

Finally, further information must be accumulated to substantiate fully the performance of these materials in the field. However, results to date indicate that these materials provide superior protection, and continued use is justified.

A detailed study of the comparative costs and application advantages of these materials may well be the subject for future presentation. However, at present it may be stated that these materials, including liberal allowances for tie-ins, crossings, spillages, etc., are available at no cost premium. Their cost is comparable with other materials commonly used at present.

Note: The application of plastic film to pipe by shrinking due to the heat of the undercoat is covered by U. S. Pat. No. 2,713,383.

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10. Personal correspondence between the author and Starr Thayer, Consulting Engineer (corrosion), 614 Southern Standard Building, Houston 2, Texas.

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Any discussion of this article not published above will appear in the June, 1957 issue.

ERRATA

Calculation of the pH of Oil Well Waters by Walter F. Rogers, Corrosion, Vol. 12, No. 12, 595t-601t (1956) Dec.

Page 596t, Column 1, Equation (2) should read:

$$W_{co_2} - W/L = m\,P_{co_2} + b \qquad (2)$$

Page 598t, Column 2, Equation (16) should read:

$$pH = 6.5 + \text{Log}\,(HCO_3^-) - \text{Log}\,(H_2CO_3) \qquad (16)$$

Testing of Coal Tar Coatings (II)—Field Exposure in Cold Climates*

By W. F. FAIR, JR., C. U. PITTMAN and M. G. STURROCK

Abstract

Details of an experiment are given in which 10-foot lengths of pipe were buried in Canada at depths of 1 through 5 feet after application of five systems of coatings and wrappings on groups of 5 pipes each. Pipes were buried after testing with an electronic holiday detector with self-registering thermometers in two pipes at each level. After a year's exposure the pipes were unearthed and tested electrically for holidays. Only a limited number of holidays were found and they were not apparently related in any way to the kind of coating or severity of exposure. Temperatures registered ranged from 25 F to 34 F. increasing with depth.

Another test of pipes exposed to atmosphere but protected from the elements was made. Results after a year showed that although temperatures of —8 F had been reached, holidays were few except in sections unwrapped but coated with unplasticized enamel. The advantages of wrapping in protecting the coating were obvious. 5.4.5

Introduction

WITH THE GROWTH of pipe line installations in Canada in recent years, considerable speculation has arisen concerning the performance of various protective coatings subjected to the severe winter conditions prevailing in Canada. In 1951, it was decided to determine the effect of low temperatures on pipe line coatings under conditions which might simulate buried enamel coated pipe lines in cold areas. It was planned to bury pipe protected with different types of coatings at an appropriate location in Canada. The coated pipe specimens were to be placed at different levels below the surface of the ground and examined a year later.

Procedure

Ten different commercially available coal tar enamel coatings from different sources covering the different kinds of hot applied pipeline coatings generally used by the industry were selected for testing. Five replicates for each coating were prepared, one each to be buried at 1, 2, 3, 4, and 5 feet below ground level, respectively.

Ten foot lengths of 3-inch diameter pipe were sandblasted and the primer designed for the particular enamel applied and allowed to dry overnight. The selected coating was then applied on a hand operated rolling rig over the whole length of each pipe.

Table 1 gives a summary of the types of coatings applied to the different pipes. Also included on the pipes were certain commonly used combinations of enamel, felt, and/or glass and Kraft. Five successive two-foot portions of each pipe were used to build the final composite systems listed in Table 2.

In all 50 pipes were used. In order to test at five different levels, five identical pipes were provided for each of the ten basic coatings. Each of these 50 pipes had five coating systems which gave a total of 250 test areas.

Holiday Testing

After the coatings were applied, they were tested with a holiday detector to ensure freedom from flaws. The pipes were then crated and shipped from Westfield, New Jersey to Port Arthur, Ontario, Canada. Upon arrival at Port Arthur, the 50 pipes were uncrated and hauled by truck a few miles to the test site. It had been planned to retest the coatings for holidays just prior to burial, but unfortunately the single holiday detector available could not be operated. For this reason only a visual examination could be made before the pipes were repaired. Very slight evidence of damage could be found by visual inspection and there was no correlation between the minor damage observed and the types of coatings applied.

Maximum and minimum self-registering thermometers were inserted in two of the pipes to be buried at each level and caps were fastened on both ends of all pipes and sealed with Bitumastic 70B Enamel before burial.

TABLE 1—Pipe Line Coatings

Pipe Nos.	Coatings	Manufacturer	Base	Type
1— 5	1	A	Coal Tar	Plasticized
6—10	2	A	Coal Tar	Plasticized[1]
11—15	3	A	Coal Tar	Semi-Plasticized
16—20	4	A	Coal Tar	Unplasticized
21—25	5	B	Coal Tar	Plasticized[1]
26—30	6	B	Coal Tar	Semi-Plasticized
31—35	7	B	Coal Tar	Unplasticized
36—40	8	C	Coal Tar	Plasticized[1]
41—45	9	C	Coal Tar	Semi-Plasticized
46—50	10	C	Coal Tar	Unplasticized

[1] AWWA Specification.

TABLE 2—Coating Systems on Pipes

Pipe Section (two-foot)	System
1	Enamel
2	Enamel + Felt
3	Enamel + Glass
4	Enamel + Glass + Enamel + Felt
5	Enamel + Glass + Enamel + Kraft

★ Submitted for publication June 28, 1955. This is the second in a series of papers by W. F. Fair, Jr. dealing with the general subject of coal tar coatings. Paper I, consisting of two installments, appeared in the November and December, 1955 issues of *Corrosion*.

W. F. FAIR, JR. is coating consultant in the Tar Products Division of Koppers Company, Inc., Verona, Pennsylvania. He received an AB from Harvard College and an MS and PhD in chemistry from Columbia University. His past experience includes research work for the Barrett Division of Allied Chemical and Dye Corpoartion, several years as Professor of Chemistry at Manhattanville College in New York City, and Senior Fellow at Mellon Institute on a Koppers Company Fellowship. For 10 years he supervised coatings development work of the Tar Products Division of Koppers Company at their Westfield, New Jersey, Laboratory. Dr. Fair served as president of the Society of Rheology from 1945 to 1949, receiving the Bingham Medal in 1950, and was on the Board of Governors of the American Institute of Physics from 1945 to 1951. In March, 1956 he became president of NACE. Previously he had been chairman of the New York Metropolitan Section, member of the Board of Directors, and vice-president.

C. U. PITTMAN is Supervisor of Technical Service of the Tar Products Division, Koppers Company, Inc. He received a BS in chemical engineering from Lafayette College (1928) and a Master of Science degree from the University of Michigan (1929). Mr. Pittman has been working in the field of bituminous materials since 1931 and bituminous coatings since 1942. He joined the Koppers Company, Inc. in 1948 after previous employment in Research, Development and Production with the Barber Asphalt Corporation, Wailes Dove-Hermiston Corporation and Pioneer Latex and Chemical Company.

M. G. STURROCK is Research Associate with Koppers Company, Inc. His principal research interests involve work with coal tar and coal tar products, a field in which he has maintained active interest since 1932. Dr. Sturrock received his PhD from McGill University.

Burial of Pipes

The particular site finally selected for the burial tests was chosen because it was an isolated plot where there would be little likelihood of the samples being disturbed or damaged. The soil in this plot consisted almost entirely of fine sandy loam, with a little clay, some iron ore, and a small proportion of pebbles. This location was reported by the City Engineer to be well above the water level. The trench was prepared roughly with a bulldozer and was then leveled off by hand to give the desired depths before the pipes were put in place. The pipes were carefully placed in the trench and were covered with at least eight inches of backfill by hand shoveling before being backfilled the rest of the way by bulldozer. After the final leveling off by hand shoveling, stakes were driven to serve as markers for the five different levels. This work was finished before August 30, 1951.

Figure 1—Pipes before backfilling.

TABLE 3—Meteorological Data

	December	January	February	Average
Winter Averages	+12 F	+ 5 F	+16 F	+11 F
Snowfall	12.3 inches	17.3 inches	8.8 inches	
Accumulated Snowfall[1]	9 inches	22 inches	20 inches	

Note: Airport Low Temperature—(—26 F) early December.
[1] Readings taken at end of month.

TABLE 4—Holidays At One Foot Level

Pipe No. (see Table 1)	Coating System (see Table 2) 1	2	3	4	5
50	1	0	0	0	0
45	0	0	0	0	0
40	0	0	1	0	0
35	0	0	0	0	0
30	0	1	3	0	0
25	0	0	0	0	0
20	0	3	1	0	1
15	0	1	1	0	0
10	0	0	0	0	0
5	1	1	1	0	0

Figure 1 shows the test site with most of the pipes in place. In Table 3 are given meteorological data obtained locally just prior to inspection in the summer of 1952. These data indicate that low atmospheric temperatures were prevailing before there was any considerable snowfall, and therefore, one might expect conditions suitable for producing low temperature below ground.

Excavation of Pipes

The pipes were carefully excavated on July 16, 1952, starting with the one-foot level. Soon after being unearthed they were transported by pickup truck about half a mile to a source of current for holiday detection.

In Table 4 are given the number of holidays found for each coating system on the ten pipes, each re-

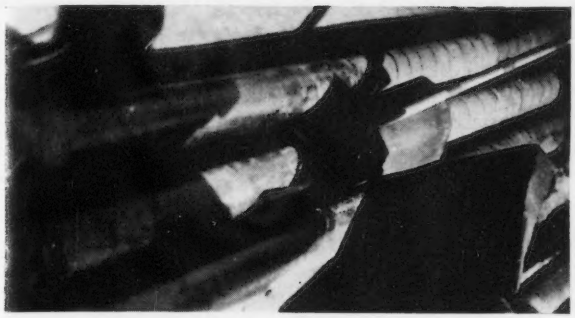

Figure 2—Holiday testing after excavation.

TABLE 5—Holidays At Various Levels

Pipe No.	Level	Coating System 1	2	3	4	5
9	2 Feet	1	1	0	0	1
8	3 Feet	0	1	0	0	0
23	3 Feet	0	*	0	0	0
43	3 Feet	0	*	0	0	0
6	5 Feet	0	0	1	0	0
21	5 Feet	0	*	0	0	0

Note: Only sections exhibiting holidays are tabulated; all other test areas were entirely satisfactory and free from holidays.
* Mechanical Damage.

TABLE 6—Temperatures Registered

Pipe No.	LEVEL 1 Ft.	2 Ft.	3 Ft.	4 Ft.	5 Ft.
50	+26 F				
10	+25 F				
49		28 F			
9		28 F			
8			30 F		
48			30 F		
7				33 F	
47				32 F	
6					34 F

TABLE 7—Holidays for Open Tunnel Test
Minimum Temperatures —8°F

Pipe No.	Coating	Manufacturer	PIPE SECTION 1 (E)	2 (E+F)	3 (E+G)	4 (E+G+E+F)	5 (E+G+E+K)
1	Plasticized	A	3	0	1	0	0
6	Plasticized	A	0	0	1	0	0
11	Semi-Plasticized	A	0	0	0	0	0
16	Unplasticized	A	34	0	0	0	0
21	Plasticized	B	0	0	0	0	0
26	Semi-Plasticized	B	0	0	0	0	0
31	Unplasticized	B	7	1	0	0	0
36	Plasticized	C	0	0	0	0	0
41	Semi-Plasticized	C	0	0	0	0	0
46	Unplasticized	C	50	0	0	0	0

spectively identified with one particular pipeline coating after removal from the one foot level. Figure 2 shows how holiday testing was done.

Test Results

It became evident at once from the small number of holidays found that there was no obvious damage pattern. Not only were the holidays few in number, but they did not occur in the test sections where they might in all probability have been anticipated. Furthermore it should be kept in mind that although these coatings were repaired after visual inspection, they had not been subjected to holiday testing from the time they left Westfield, New Jersey. It is considered indeed remarkable that so little damage was done during the crating, shipping, uncrating, burial, and excavation. In view of the above, it is believed that no significance can be attached to the slight damage exhibited by a few of the coating systems.

The observations made for pipes buried at the other four levels are given in Table 5. Again it is obvious that there was relatively little damage done to any of the coatings under the test conditions.

The self registering maximum-minimum thermometers sealed in pipes at the different levels were removed and read. The temperatures registered are presented in Table 6.

It is apparent from the above results that frozen ground is such a good thermal conductor that subsurface heat can counteract to a great extent extremely low atmospheric temperatures, and provide relatively moderate temperatures underground at levels only slightly below the earth's surface even during periods of low atmospheric temperatures.

Ground-Level Tests

In view of the slight pattern-free damage done to the samples in the above described tests, it was decided to place one group of test specimens on the ground and to continue the test through another winter. One complete set comprising one of each of the coated pipes was placed unburied in the center of a long open-end large diameter tunnel located at ground level in the Koppers Company, Ltd., Port Arthur Plant. This tunnel kept off sunlight, snow, rain, dirt, debris, and the like, but permitted exposure of the samples to temperature conditions very close to atmospheric. The registering thermometers were reset and were located again in the pipes.

In August, 1953, the pipe samples were again inspected by holiday testing at the tar plant. The samples had reached a minimum of —8 F during the winter, but had surprisingly few holidays except for the unplasticized enamel, unwrapped sections. Holiday testing counts for the different systems are given in Table 7.

Considered extremely significant is the improvement afforded by glass and felt on the unplasticized enamels, all samples of which exhibited excessive jeeping at the low exposure temperature, unless fortified by glass or shielded by felt or both. Combined with glass and/or felt, the undisturbed hard unplasticized enamels had resisted low temperature embrittlement.

The plasticized types of enamels generally resisted embrittlement even without the aid of reinforcements or wrappers. The few holidays detected are believed to be without significance, as far as the different coatings are concerned.

Summary and Conclusions

A fairly comprehensive short time study of behavior of a variety of coal tar coatings and wraps

applied to short test sections of pipe specimens in a cold climate has been reported. Certain tentative conclusions can be drawn:

1. Subsurface temperatures registered were not sufficiently low to affect materially the coatings in spite of low atmospheric temperatures.
2. Exposure unburied at atmospheric temperatures reduced the pipe interior to a low of —8 F, which was detrimental to unwrapped unplasticized enamel coatings.
3. All plasticized enamel coatings with and without wraps and the wrapped unplasticized coatings withstand the —8 F exposure.

On the basis of the above, it appears that exposure before backfilling is a major factor in low temperature exposure damage.

Any discussion of this article not published above will appear in the June, 1957 issue.

TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

NACE TECHNICAL COMMITTEE REPORTS

Publication No. 57-6

Acidproof Vessel Construction With Membrane and Brick Linings

A Report of NACE Technical Unit Committee T-6K On
Corrosion Resistant Construction With Masonry and Allied Materials*

Abstract

Following a brief history of the development of brick-membrane vessel construction and the cements used, types of vessels and supporting structures are described. Design formulae are given. Recommended specifications and techniques are described briefly. Membrane linings commonly used are listed and described, technique of holiday testing given and cements considered with respect for their suitability in different kinds of construction and for different types of service.

Function, design considerations, jointing techniques, temperature criteria and physical characteristics of principal brick types related to construction are described.

Tabular data on ratings of different kinds of membrane (including lead) versus two representative temperatures and numerous corrosive acids, alkalis, salts, gases, organic materials and bleach solutions are given. Stability of principal cements versus representative temperatures and corrosives are tabulated as are physical and mechanical properties of typical cements, working time for cements, physical properties of red shale brick and relative cost data.

5.4.3

Introduction

Purpose

Technical Unit Committee T-6K on Corrosion Resistant Construction with Masonry and Allied Materials was organized for the purpose of collecting and disseminating up-to-date information on the use of masonry and allied materials for chemical resistant vessels, stacks, floors and related equipment. This report is the first of several that will be developed by this commitee.

Terminology

The use of proprietary trade names has been avoided. In most cases proprietary trade name materials fall into general classes for membranes, cements and acid-proof masonry shapes. The data presented have been collected for these general classes.

Presentation

Descriptions of materials and discussions on their usefulness and limitations are brief and limited to facts that provide basic information regarding their selection and use. It is recognized that there are materials commercially available not covered in this report that will give good service. These are of relatively minor importance in American industry and outside the scope of this report. It is impossible to include all the variations and combinations of uses of available materials for all specific applications. Where the user lacks experience with this type construction, it is suggested the advice and recommendations of reputable suppliers or contractors be obtained. The report is divided into four main sections:

1. Vessels or supporting structures
2. Membrane linings
3. Cements or mortars
4. Masonry linings

Development History

During World War I new emphasis was placed on chemical developments. As a result the need for better equipment to handle more corrosive conditions developed also. These circumstances gave birth to the development of chemical resistant masonry construction for tanks and related equipment.

Attempts were made initially to obtain protection through the use of tars and asphalts. These generally were unsatisfactory because they lacked chemical resistance and had poor resistance to thermal and mechanical changes. Use of stone and clay brick linings followed as a natural step. Mortars first employed included lime, gypsum and Portland cement. These combinations generally were unsatisfactory. A period followed, in the early 20's, in which coatings based on ground quartz, barytes and sodium silicate were used to brush coat masonry work for protection. Quartz powder and sodium silicate combinations were used as mortars, but they did not harden properly. This difficulty led to the development, in 1925, of the first of the chemically setting silicate cements. Almost all this development work was done in Germany.

In 1930 the first of the chemically setting resin cements, based on phenol formaldehyde and a silicate filler was developed in Germany. A major improvement was made in 1937 and improvements have continued since that time. Development of resin cements based on furfuryl alcohol followed. Cements based on furfuryl ketone are available now.

The only other cement used in any quantity during this development period was the sulfur-based heat-and-pour type. This cement, which consisted simply of sulfur and a siliceous aggregate, was introduced in this country in 1925. A major improvement in mechanical properties and over-all use suit-

* L. R. Honnaker, E. I. duPont de Nemours & Co., Inc., Wilmington, Del., chairman.

ability was made in 1934 when means of plasticizing this material were first developed. Improvements have continued.

First of the masonry shapes used in chemical resistant linings were made from sandstone, primarily because of the ease with which the desired large shapes could be made. Granite replaced sandstone because of its greater density and higher compressive strength. Granite, however, still left much to be desired and development of fire clay shapes suitable for chemical service followed. Ordinary building brick has poor resistance to acid because of its relatively high lime content. In more recent years masonry shapes made from shale clay have been developed to provide shapes of minimum porosity. Carbon and impervious graphite shapes also have been developed for special services including strongly alkaline conditions.

Masonry-lined vessel construction has been developed now to the point where economical and reliable equipment for a great many services is provided. This type of construction will satisfactorily handle many service conditions too corrosive for even the most highly alloyed stainless steels or special metals and alloys.

Detailed information on the suitability and use of present-day cements and masonry shapes, which are the basic elements of masonry linings, is given in the following sections under the respective headings.

Vessels or Supporting Structures

Vessels that are to be lined with a membrane lining material and masonry lining shapes are made mainly of steel or reinforced concrete. Wooden vessels have been used in some instances but are not covered in this report because of limited use and interest. The basic requirement of any supporting structure is that it be dimensionally stable and sufficiently rigid to support loads involved.

Steel

Steel vessels are the most commonly used because steel is relatively easy to fabricate. The many vessel shapes and sizes required can be made readily. Welded construction is always desirable because it is important to have smooth, continuous surfaces where membrane linings are used. Grades of steel generally used fall within the requirements of ASTM Specifications A-283 or A-285. Tanks of cylindrical design are used frequently in preference to rectangular shape for reasons of economy, pressure rating and stability of the brick linings.

Thickness of steel in shell plates for cylindrical vessels should be as follows: (Except that ¼-inch minimum thickness is recommended for tanks over 4 feet in diameter.)

1) When the temperature differential between brick lining and steel shell is negligible or when expansion joints are provided in the brick lining, it is suggested steel tanks be designed in accordance with the usual rules for accommodating forces imposed by the internal pressure, the weight of the vessel, lining and contents and by wind, shock, or other loads that may occur. If operating pressure is to be 15 psig or less, consideration should be given to designing the vessel to permit hydrostatic testing at twice the operating pressure. If vessels are to operate at pressure above 15 psig, it is suggested they be designed to meet requirements of the ASME Code.

2) When a temperature differential between the brick lining and steel shell will exist and expansion joints are not provided in the brick lining, it is suggested the thickness of steel shell be determined by the following equation:

$$t_s = \frac{t_b E_b}{S_s}\left(\alpha_b \Delta T_b - \alpha_s \Delta T_s - \frac{S_s}{E_s}\right) + \frac{pD}{2S_s}$$

(When the term in parenthesis is negative it indicates the steel tank will expand more than the brick lining or that the stress in the steel shell caused by expansion of the brick lining is less than the maximum allowable S_s. The thickness of the shell then should be determined from the internal pressure.)

Where:

t_s = Thickness of shell—inches
t_b = Thickness of brick lining—inches
E_s = Modulus of elasticity for steel—psi (use 30×10^6 psi)
E_b = Modulus of elasticity in compression for brick lining—psi (may vary from 2×10^6 to 7×10^6 psi)
S_s = Allowable stress for shell—psi (use 13,750 psi)
S_b = Allowable compressive stress for brick lining—psi (may vary from 4000 to 10,000 psi)
α_s = Coefficient of expansion for steel inches per inch per degree F 6×10^{-6}
α_b = Coefficient of expansion for brick inches per inch per degree F 3×10^{-6} to 6×10^{-6}
ΔT_s = Average temperature rise of steel—F
ΔT_b = Average temperature rise of brick—F
p = Maximum allowable internal pressure, psi
D = Inside diameter of shell—inches

When the thickness of the shell has been established, compression stress in the brick should be determined by the following equation:

$$S_b = E_b \frac{b\,T_b - s\,T_s}{\frac{t_b E_b}{t_s E_s} + 1}$$

Should the compressive stress of the brick exceed a safe value, expansion joints may be provided, the thickness of the brick lining may be increased, or stronger brick used. A reduction in the thickness of of the steel also will reduce the stress in the brick.

Flat bottom thickness should be ⅜-inch minimum or sufficient to limit the deflection to 1/32-inch/ft. of the span. Consideration should be given to warpage of flat bottoms which may result from welding. This can be reduced by increasing thickness.

Shells and heads must be made stiff enough to avoid deformations that will seriously crack the brick lining and allow it to disintegrate or fall.

Joints in all surfaces that are to be covered by a membrane lining should be made by butt welding. Lap and riveted joints should not be used. Welds at inside and outside corners should be finished so that they may be ground to 3/16-inch minimum radius.

Vessels should be hydrostatically tested and repaired as may be necessary, before any lining work is started.

Concrete

The design and installation of concrete tanks, particularly rectangular shapes, warranted careful consideration of a number of engineering details beyond the scope of this report. Excellent technical

articles on concrete tank construction, with and without prestressing, are available upon request to the Portland Cement Association, 33 West Grand Avenue, Chicago 10, Illinois. It is suggested the reader contact this organization for detailed engineering information on their specific requirements.

Special attention should be given to form work for tanks since bulging, sagging, etc., in the tank may cause the lining to fail prematurely. Care should be taken to insure the inside forms are adequate to prevent bowing in towards the center. It is better to have bowing out rather than in. In large rectangular vessels it is often recommended to bow and batter the inside walls to place the chemical resistant masonry lining in compression upon thermal expansion. All concrete tanks, regardless of shape, should be reinforced with steel. Where practical, the vessel should be poured monolithically to avoid "dry joints" which are potentially weak.

In addition to good engineering design details, it is desirable to have a smooth interior surface when a flexible membrane type lining is to be applied. A wood float finish generally is desirable. Bolt holes, honeycombed surfaces, etc. should be filled with a stiff Portland cement mortar. Rough projections or high spots should be removed by chipping or use of abrasive stone. All loose and foreign materials, particularly oil and grease, should be removed. The finished tank should be given a hydrostatic test for at least 48 hours and repairs made as necessary before lining work is started. If the concrete shell extends below the water table, the exterior should be waterproofed before backfilling.

Membrane Linings

It is almost always desirable to use a membrane lining between the vessel shell and the acidproof brick. This will protect the vessel shell from chemical attack by the solution which permeates the brick lining through pores or cracks. Materials most widely employed today for this purpose are sheet elastomers and plastics that vary in thicknes from $\frac{3}{32}$ inch to $\frac{1}{4}$ inch. These are bonded continuously to the steel or concrete vessel shell by cementing. Asphaltic materials frequently are used on concrete vessels. Sheet lead, used extensively in the past, is being replaced by elastomer and plastic materials.

Serviceability of and general preference for membrane materials used between vessel shell and brick lining are summarized in Table 1. As is the case with almost all chemically resistant materials, the upper service temperature limit will vary with chemical environment and type of exposure involved. Membrane materials may be used satisfactorily behind brick in many chemical services that would cause early failure if the brick facing were not present. Experience has shown it is desirable to provide brickwork sufficiently thick to hold membrane temperatures to about 150 F maximum. Lower temperatures may be necessary for some services due to aggressiveness of chemicals involved. Reinforced acidproof cements have seen limited service as membrane linings. A report of NACE Unit Committee T-6A on Reinforced (Faced) Tank Linings describes these materials.

In the application of sheet elastomer and plastic membrane materials it is essential that the surface being lined be smooth, clean and dry. All projections and welds should be ground smooth, weld spatter removed and all corner welds ground to $\frac{3}{16}$-inch minimum radius. In the case of steel shells, it is necessary to sandblast the surfaces to be lined. The prime coat of the adhesive system should be applied immediately after sandblasting to prevent rusting.

Curing Procedures

Most elastomer materials (natural and synthetic rubber) require curing at temperatures of 180-220 F after lining is completed. This generally is accomplished by introducing low pressure exhaust steam directly into the tank or by filling the tank with water and bringing it near to boiling by steam sparging. Hot air is used occasionally and small tanks lined in shops sometimes are cured in autoclaves. Curing time will vary from 12-36 hours, depending upon temperature and elastomer used. Precured sheet elastomer materials (Neoprene and butyl) recently have been introduced for membrane use and are receiving favorable attention because a curing operation is not required. Ambient temperature curing cements are used and the brick lining work can proceed immediately following application of the membrane lining. Plastic membrane materials (vinyl, PVC, etc.) are applied with ambient temperature setting cements and heat curing is not required. Joints are heat sealed and a reinforced butt strap is applied over the joints and heat sealed to the sheet at the edges.

Testing for Holidays

It is desirable to spark test all elastomer and plastic linings to detect pinholes, discontinuities at seams, etc. Repair and retesting should be completed before the brickwork is started. Precautions should be taken in testing carbon-filled elastomers, such as Neoprene, to prevent burning holes in the lining. Spark testing of linings in concrete tanks may be accomplished by using metallic pigmented primers on the concrete. As a compromise, fine wire may be embedded at the seams between adjoining sheets to pick up "leaks" at seams.

Asphaltic Materials

Hot-applied asphaltic materials, both plain and reinforced, frequently are used as membrane linings in concrete tanks. They are used generally at thicknesses of about $\frac{3}{8}$ inch. Where vertical walls are over about 4 feet in height, it is desirable to reinforce the asphaltic materials to prevent failure as a result of cold flow. Reinforcement commonly is obtained by adding filler materials such as silica, asbestos fiber, or by using suitable glass cloth.

Lead As Membrane Lining

Lead, in sheet and homogeneously bonded forms is used as a membrane lining in brick-lined tanks, particularly for sulfuric acid service with and without organics present. Its use, however, is decreasing because more satisfactory service is given by elas-

tomers and plastic lining materials where they can be used. It always is desirable to have chemically resistant linings continuously bonded to the vessel so that damage from leaks is localized and the leaks can be located readily. Homogeneously bonded lead has this feature, but its cost generally makes its use unattractive. Loose sheet lead linings cannot be installed tightly against the shell. Creep and cracking

TABLE 1—Membranes for Use With Brick Linings

Resistance to Corrosives at Two Temperature Levels at Surface of Membrane Behind Brick

Legend: E—excellent. G—good, occasionally used. F—fair, for limited service only. P—poor, not recommended.

CORRODENT	Soft Natural Rubber 75 F	Soft Natural Rubber 150 F	Neoprene 75 F	Neoprene 150 F	Plasticized Polyvinyl Chloride 75 F	Plasticized Polyvinyl Chloride 150 F	Asphaltics 75 F	Asphaltics 150 F	Lead 75 F	Lead 150 F
ACIDS—										
Acetic, 10%	F	P	F	P	F	P	P	P	P	P
Acetic, glacial	P	P	P	P	P	P	P	P	F	P
Benzene, sulfonic, 10%	E	E	G	F	E	E	E	E	G	F
Benzoic, sat'd.	E	E	E	E	E	E	E	E	P	P
Boric, sat'd.	E	E	E	E	E	E	E	E	G	G
Butyric, 100%	F	P	F	P	P	P	P	P	P	P
Chloroacetic, 10%	P	P	F	P	F	P	P	P	P	P
Chromic, 5%	P	P	P	P	E	F	G	F	E	E
Chromic, 10%	P	P	P	P	G	F	G	F	E	E
Citric, 10%	E	E	E	E	E	E	E	E	E	E
Fatty Acids (C6 and up), 100%	P	P	F	P	G	F	P	P	G	G
Fluosilicic, 40%	E	E	G	G	E	E	P	P	..	..
Formic, 90%	G	F	G	F	F	P	F	P	F	P
Hydrobromic, 48%	G	F	F	P	E	F	E	G	P	P
Hydrochloric, 37%	E	G	F	P	E	F	E	E	P	P
Hydrocyanic, 25%	G	G	E	E	E	E	E	E	G	F
Hydrofluoric, 40%	G	F	G	F	E	P	F	F	F	P
Hypochlorous, 10%	E	G	P	P	E	P	P	P	P	P
Lactic, 25%	E	E	E	E	E	E	E	E	P	P
Maleic, 25%	G	G	G	F	G	F	G	F	P	P
Nitric, 5%	P	P	F	P	E	E	G	G	P	P
Nitric, 10%	P	P	F	P	E	E	G	G	P	P
Nitric, 20%	P	P	F	P	E	F	G	F	P	P
Oleic, 100%	F	P	F	P	E	F	F	P	P	P
Oxalic, 20%	G	G	G	G	E	F	E	E	P	P
Perchloric, 40%	G	F	G	F	E	P	..	..	..	..
Phosphoric, 85%	E	E	E	E	E	E	E	E	E	G
Picric, 10%	F	P	F	P	P	P	P	P	G	G
Stearic, 100%	F	P	F	F	E	F	F	P	G	F
Sulfuric, 50%	E	E	E	E	E	E	E	E	E	E
Sulfuric, 70%	F	P	F	P	E	P	F	P	E	E
Sulfuric, 93%	P	P	P	P	P	P	P	P	G	P
Oleum, (110% Sulfuric)	P	P	P	P	P	P	P	P	P	P
ALKALIES—										
Ammonium hydroxide, 28%	G	G	G	G	E	F	G	F	G	F
Calcium hydroxide, sat'd.	E	E	G	G	E	F	G	F	G	F
Potassium hydroxide, 25%	E	E	E	E	E	G	G	F	G	F
Sodium hydroxide, 25%	E	E	E	E	E	G	G	F	G	F
ACID SALTS—										
Alum, 10%	E	E	E	E	E	E	E	E	E	E
Ammonium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	G	F
Copper chloride, nitrate, sulfate	E	E	E	E	E	E	E	E	E	E
Ferric chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E	F	P
Nickel chloride, sulfate, 10%	E	E	E	E	E	E	E	E	E	G
Stannic, chloride, 100%	E	E	G	F	E	E	E	E	G	F
Zinc chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E	G	F
ALKALINE SALTS—										
Barium sulfide	E	E	E	E	E	E	F	P	E	E
Sodium bicarbonate, 10%	E	E	E	E	E	E	E	E	E	E
Sodium carbonate, 10%	E	E	E	E	E	E	G	F	E	E
Sodium sulfide	E	E	E	E	E	E	F	P	G	G
Trisodium phosphate, 10%	E	E	E	E	E	E	P	P	P	P
NEUTRAL SALTS—										
Calcium chloride, nitrate, 10%	E	E	E	E	E	E	E	E	G	F
Magnesium chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E	G	F
Potassium chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E	G	F
Sodium chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E	G	G
GASES—										
Chlorine, dry	G	F	P	P	E	F	E	E	E	E
Chlorine, wet	P	P	P	P	E	F	E	F	G	G
Hydrogen sulfide	G	F	E	E	E	E	E	E	E	G
Sulfur dioxide, dry	G	F	E	E	E	E	E	E	E	G
Sulfur dioxide, wet	E	E	E	E	E	G	E	E	E	G
ORGANIC MATERIALS—										
Acetone, 100%	G	F	G	F	P	P	P	P	E	E
Alcohol, methyl, ethyl, 95%	E	E	E	E	E	F	E	E	E	E
Aniline	F	P	F	P	P	P	P	P	E	E
Benzene	P	P	P	P	P	P	P	P	E	E
Carbon tetrachloride	P	P	P	P	P	P	P	P	G	G
Chloroform	P	P	P	P	P	P	P	P	G	G
Ethyl acetate	P	P	P	P	P	P	P	P	E	E
Ethylene dichloride	P	P	P	P	P	P	P	P	E	E
Formaldehyde, 37%	P	P	G	P	G	E	F	F	P	P
Phenol, 5%	..	..	..	..	P	P	P	P	E	G
Trichloroethylene	P	P	P	P	P	P	P	P	G	G
BLEACH SOLUTIONS—										
Chloride dioxide acid solutions	F	P	P	P	E	E	P	P	F	P
Chlorine dioxide neutral solutions	P	P	P	P	E	E	P	P	F	P
Chlorine dioxide alkaline to pH 11	P	P	P	P	E	E	P	P	P	P
Sodium hypochlorite acid neutral or alkaline to pH 11 (5% sol.)	P	P	F	P	E	P	F	F	P	P
Sodium hypochlorite above pH 11, (5% sol.)	P	P	F	P	E	P	F	F	P	P

generally occur because of lack of support especially if the temperature of the lining is over about 150 F. Movement of the lead also will contribute to damage of the brick lining. Lead-covered vertical steel straps bolted through the lining and the shell have been used in some instances to support the lead. This, however, requires that the brick be cut or offset along the support strap to accommodate the added thickness of the lining at this point. This is undesirable generally.

Cements

Chemical resistant cements are intended primarily to join acidproof shapes when they are exposed to corrosive acids, alkalies, salts, or solvents. With the exception of sulfur-base cements, these mortars can be applied by appropriate modifications of bricklayer and tile setter techniques.

Sulfur cements are applied by melting the solid material to obtain a free-flowing liquid. The liquid then is poured between spaced bricks to form the masonry structure. Most other types of cements are supplied as two-package systems which are combined to produce the mortar just before use. These mortars set by chemical action and become hard and chemical resistant.

Major types of commercial chemical resistant cements are: Furan resin cements, phenolic resin cements, sulfur cements and silicate cements. Resistance of these cements to specific chemicals and their important physical properties are summarized in Tables 2 and 3 respectively. Test data are not available for each condition shown in Table 2, but it is believed the ratings will apply for indicated conditions.

Furan Cements

Furan cements are the most versatile of the chemical resistant cements now used. No other cement combines acid, alkali, salt and solvent resistance with a comparatively low cost. This type cement was introduced in 1940 and its use has been increasing rapidly since.

Furan resins consist of:

1. Low furfuryl alcohol polymer dissolved in excess furfuryl alcohol
2. Furfuryl-furfuryl polymer
3. Furfuryl-ketone resins

Acid catalysts are used to condense these products to required viscosity at temperatures below 192 F. When the required stage is attained the catalyst is neutralized, washed and water is removed under reduced pressure.

TABLE 2—Stability of Typical Chemical Resistant Cements

Legend: E—excellent, G—good, occasionally used. F—fair, for limited service only. P—poor, not recommended.

CORRODENT	Furan 75 F–250 F		Phenolic 75 F–250 F		Sulfur 75 F–190 F		Silicate 75 F–750 F	
ACIDS—								
Acetic, 10%	E	E	E	E	E	E	E	E
Acetic, glacial	E	E	E	G	G	N	E	E
Benzene, sulfonic, 10%	E	E	E	E	E	E	E	E
Benzoic, sat'd	E	E	E	E	E	E	E	E
Boric, sat'd	E	E	E	E	E	G	E	E
Butyric, 100%	E	E	E	E	G	N	E	E
Chloroacetic, 10%	E	E	E	E	F	N	E	E
Chromic 5%	F	P	G	P	E	G	E	E
Chromic, 10%	P	P	F	P	E	G	E	E
Citric, 10%	E	E	E	E	E	E	E	E
Fatty Acids (C^6 and up), 100%	E	E	E	E	G	F	E	E
Fluosilicic, 40%	E*	E*	E*	E*	E*	E*	N	N
Formic, 90%	E	E	E	E	F	N	E	E
Hydrobromic, 48%	E	E	E	F	E	E	E	E
Hydrochloric, 37%	E	E	E	E	E	G	E	E
Hydrocyanic, 25%	E	E	E	E	E	E	E	E
Hydrofluoric, 40%	E*	E*	E*	E*	E*	E*	N	N
Hypochlorous, 10%	P	P	F	P	F	P	E	E
Lactic, 25%	E	E	E	E	E	E	E	E
Maleic, 25%	E	E	E	E	E	F	E	E
Nitric, 5%	F	P	G	P	E	E	E	E
Nitric, 10%	P	P	P	P	E	G	E	E
Nitric, 20%	P	P	P	P	E	F	E	E
Oleic, 100%	E	E	E	E	E	F	E	E
Oxalic, 20%	E	E	E	E	E	E	E	E
Perchloric, 40%	E	E	E	E	E	E	E	E
Phosphoric, 85%	E	E	E	E	E	E	E	E
Picric, 10%	E	E	E	E	E	E	E	E
Stearic, 100%	E	E	E	E	E	F	E	E
Sulfuric, 50%	E	E	E	E	E	E	E	E
Sulfuric, 70%	E	P	E	P	E	F	E	E
Sulfuric, 93%	P	P	G	P	G	P	E	E
Oleum, 110%	P	P	P	P	P	P	E	E
ALKALIES—								
Ammonium hydroxide, 28%	E	E	P	P	P	P	P	P
Calcium hydroxide, sat'd	E*	E*	F	P	P	P	P	P
Potassium hydroxide, 25%	E*	E*	P	P	P	P	P	P
Sodium hydroxide, 25%	E*	E*	P	P	P	P	P	P
ACID SALTS—								
Alum, 10%	E	E	E	E	E	E	E	E
Ammonium chloride, nitrate, sulfate	E	E	E	E	E	E	E	E
Copper chloride, nitrate, sulfate	E	E	E	E	G	F	E	E
Ferric chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E
Nickel chloride, sulfate 10%	E	E	E	E	E	E	E	E
Stannic, chloride, 100%	E	E	E	E	E	F	E	E
Zinc chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E
ALKALINE SALTS—								
Barium sulfide	E	E	P	P	P	P	P	P
Sodium bicarbonate, 10%	E	E	E	E	E	F	F	P
Sodium carbonate, 10%	E	E	E	P	E	P	P	P
Sodium sulfide	E	E	P	P	P	P	P	P
Trisodium phosphate, 10%	E	E	G	P	G	P	P	P
NEUTRAL SALTS—								
Calcium chloride, nitrate, 10%	E	E	E	E	E	E	E	E
Magnesium chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E
Potassium chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E
Sodium chloride, nitrate, sulfate, 10%	E	E	E	E	E	E	E	E
GASES—								
Chlorine, dry	F	P	F	P	F	P	E	E
Chlorine, wet	P	P	P	P	P	P	E	E
Hydrogen sulfide	E	E	E	E	E	E	E	E
Sulfur dioxide, dry	E	E	E	E	E	E	E	E
Sulfur dioxide, wet	E	E	E	E	E	E	E	E
ORGANIC MATERIALS—								
Acetone, 100%	E	E	E	E	P	P	E	E
Alcohol, methyl, ethyl, 95%	E	E	E	E	E	E	E	E
Aniline	P	P	F	P	P	P	F	P
Benzene	E	E	E	E	P	P	E	E
Carbon tetrachloride	E	E	E	E	P	P	E	E
Chloroform	E	E	E	E	P	P	E	E
Ethyl acetate	E	E	E	E	P	P	E	E
Ethylene dichloride	E	E	E	E	P	P	E	E
Formaldehyde, 37%	E	E	E	E	E	E	E	E
Phenol, 5%	E	E	E	E	P	P	E	E
Trichloroethylene	E	E	E	E	P	P	E	E
BLEACH SOLUTIONS—								
Chlorine dioxide acid solutions	P	P	P	P	F	P	G	G
Chlorine dioxide neutral solutions	P	P	P	P	F	P	G	G
Chlorine dioxide alkaline to pH II	P	P	P	P	P	P	P	P
Sodium hypochlorite acid, neutral or alkaline to pH 11, 5%	P	P	F	P	F	P	F	F
Sodium hypochlorite, above pH 11, 5%	P	P	P	P	P	P	P	P

* Carbon-filled.

Cement mortar is made by mixing a liquid furan resin with a powder consisting of an inert filler, such as coke flour or silica and a strong acid catalyst. Acid causes further polymerization to form a cross-linked infusible resin.

The liquid resin and the filler containing the acid catalyst are mixed intimately to produce the resin mortars just before use. The mixing ratio will vary from about two parts powder to one part liquid by weight for a typical carbon-filled product to a three to one ratio for silica-filled cements. These ratios can be varied somewhat, depending upon the temperature and the individual preference of the workmen applying the cement. Mixing usually is done in small batches in an enameled mixing pan with a trowel. After mixing, the mortar should be spread out immediately, in layers not exceeding about ¾ inch in thickness in flat mortar trays, in order to dissipate exothermic heat.

When working at temperatures of 80 to 90 F, material waste may be avoided by mixing small batches. The liquid resin and powder should be cooled to 60 F before mixing. All equipment should also be cooled by placing the mortar mixing box and pan in ice water, care being taken to prevent water getting in the mix. Granulated dry ice also may be added. Furan resin cement mortars should not be mixed in direct sunlight. When working at temperatures below 65 F, the liquid resin and powder should be kept warm but not above 80 F. If at all practical, the working area should be heated with portable blowers or stoves.

The working time of furan resin cements is highly dependent upon temperature. When required fast setting cements are available commercially. These are useful when the ambient temperature is below 60 F and also for erection of acid brick tank walls when rapid setting is desirable to permit rapid construction of vertical or domed sections.

Setting Time

After mixing, resin cement mortars gradually harden as the curing process takes place. The preliminary set is obtained in 4 to 16 hours, depending upon the thickness of the joint and the ambient temperature. Brickwork designed for acid resistance may be placed in service as soon as the initial set has been obtained because acids will promote further cure. For use under alkaline or neutral conditions, or in the presence of solvents, the mortar should be allowed to reach its final set. This stage is not readily determined in the field but usually requires 4 to 10 days, depending upon temperature. Introduction of dry heat by hot-air blowers should be considered where the vessel must be placed in service before final setting.

Methods for determining initial and final setting time are given in ASTM Specification C-308-53T. Typical working and setting times for a furfuryl alcohol cement are shown in Table 4.

Chemical resistance of furan cements is summarized in Table 2. They are almost completely resistant to nonoxidizing acids, alkalies, salts and most solvents at temperatures up to 380 F. Silica and asbestos fillers cannot be used in the presence of strong alkaline materials or fluorine containing-acids and salts. Carbon fillers should be used where these chemicals are to be encountered.

TABLE 3—Physical and Mechanical Properties of Typical Chemical Resistant Cements

Property	Furan[1]	Phenolic[1]	Sulfur[2]	Silicate[2]
Tensile Strength, lb./sq. in.	1,200	1,200	400	350
Compressive Strength, lb./sq. in.	12,000	10,000	4,000	2,500
Flexural Strength, lb./sq. in.	5,000	4,000	.....	.....
Modulus of Rupture, lb./sq. in.	1,400	1,400	1,000	.....
Specific Gravity	1.4	1.4	2.2	2.0
Coefficient of Expansion, in./in. °F. x 10^{-6}	10	10	8	7
Adhesion Wire-cut brick lb./sq. in.	500	400	400	100
Water Absorption, percent	0.2	0.2	0.5	8–15
Maximum Service Temp. °F.	375	360	200	1,000

[1] Carbon filled.
[2] Silica filled.

Adhesion

Adhesion to nonglazed brick or tile surfaces is very good and far superior to that of hydraulic cement mortars. A certain amount of adhesion is required, but outstanding adhesion values are not essential in acid brick tank linings because the joints are seldom subjected to tensile stresses. Typical physical properties are shown in Table 3.

Furan resin cements will not adhere to unprimed concrete or metallic surfaces because of the reaction of the acid catalyst. Several satisfactory primers are available and should be used for such applications.

Uncatalyzed furan resins are stable at ordinary temperatures for at least five years. This is a marked advantage over cements based on phenolic resins, which require low temperature storage conditions. The powder should be stored in dry areas to prevent moisture absorption.

All furan cements are inherently black in color no matter what type of filler is used.

Furfuryl alcohol and its polymers have rather mild odors. However, resins made with furfuryl or formaldehyde usually have strong, penetrating odors which make them obnoxious when used in confined or poorly ventilated areas. Certain organic acids or catalysts used in some resin cements will cause severe dermatitis on the hands and arms of sensitive persons.

Setting of furan cements is dependent on an acid reaction. Contamination by alkaline substances, such as Portland cement and dust will interfere seriously with the curing reaction. Because these are almost always present on construction jobs suitable precautions should be taken.

Phenolic Cements

Chemical resistant phenolic resin cements were introduced in Germany during 1930. They have been widely used in the chemical industry in America since 1935 but are gradually being displaced for many applications by the more versatile furan cements. Phenolic resin cements are based on low molecular weight phenol-formaldehyde condensation products prepared under alkaline conditions. The reaction can be stopped at the desired viscosity range by neutralization of the alkaline catalyst. The resin

mortar is prepared by combining the liquid phenolic resin suitably modified for optimum ease of mixing with an acid-containing filler which causes further polymerization to the infusible, highly cross-linked stage.

Phenolic resin cements are used in the same manner as furan cements. Both carbon and silica-filled varieties are somewhat more difficult to mix because of the inherent stickiness of the resin. The mixing ratio is about two to one powder-to-liquid for the carbon filled and 2½ to one for the silica-filled cements.

Working times at various temperatures for typical carbon-filled phenolic cements, as determined by ASTM Method C-308-53T, are given in Table 4. Initial and final setting times are essentially the same for both carbon-filled and silica-filled phenolic resin cements. The final setting times for typical cements are given in Table 4.

Resistance

Phenolic resin cements have characteristically poor resistance to caustics but show good resistance to milder alkalies, especially at lower temperatures. Resistance to oxidizing agents, such as dilute nitric acid and sulfuric acid, at concentrations between 60 and 90 percent is somewhat superior to that of furan resin cements, hence they frequently are recommended for use at ambient temperatures involving these applications.

Physical properties of a typical cured carbon-filled phenolic resin are much the same as those obtained with furan cements. Typical values are shown in Table 3.

Phenolic resins have the odor typical of free phenol. This usually is not considered objectionable, but specially deodorized formulations are available for use in confined spaces.

Polymerization

The low molecular weight resins used in phenolic resin cements are basically unstable and tend to polymerize further even though the original alkaline catalyst is completely neutralized. This reaction is evidenced by a gradual thickening of the resin and eventual appearance of an aqueous layer on the surface. Slightly thickened resins still can be used in preparing mortars, but they are more difficult to use when free water appears. For this reason all liquid phenolic resins should be stored at temperatures of 65 F or lower. Under these conditions a shelf life of at least three months will be obtained.

Since phenolic resin cements require considerably more acid to obtain practical rates of setting, contamination by alkaline impurities is less critical than with furan cements. The same precautions against contact with Portland cement, dust and construction dirt during application should be observed.

Phenolic resin cements undergo decomposition at about 360 F and should not be used at services above this temperature.

Sulfur Cements

Plasticized sulfur cements essentially are mixtures of sulfur and inert fillers with minor amounts of plasticizers. The addition of the plasticizer is important in reducing the inherent brittleness and shrinkage of simple sulfur and sand mixtures. In contrast to resin cements discussed previously, sulfur cements are applied as hot melt materials. This type of material has been used industrially for over a half century.

The major advantages of sulfur cements over the resin cements are lower cost and somewhat superior resistance to oxidizing agents. Their disadvantages are low temperature limitation and poor resistance to alkalies and nonpolar organic solvents.

The application of sulfur cements consists of simple melting and resolidifying processes. These changes are physical rather than chemical in nature. They set immediately upon cooling. Sulfur cements with either graded silica or carbon fillers are available commercially. The carbon-filled type is used primarily for service in hydrofluoric or fluosilicic acids. The type of plasticizer most often used commercially in sulfur cements is Thiokol, a polysulfide rubber. The amount of plasticizer may be varied over a wide range, depending upon the degree of ductility required for the end use. In addition to reducing shrinkage and brittleness, the plasticizer also minimizes the loss of strength caused by repeated temperature changes.

The recommended type of heating equipment consists of a steel or cast iron kettle of 2 to 5 gallons capacity suspended in a metal jacket so that the sides, as well as the bottom, of the kettle are heated uniformly. Heat is supplied generally by a burner using compressed liquid fuel.

Cements are supplied usually as cast ingots weighing from 2 to 5 pounds. The ingots are broken up, placed in a melting pot and melted over a low uniform fire. The melt should be stirred continuously with a metal rod or ladle until the cement becomes water-thin and pours readily. The recommended temperature range is 265 to 290 F. If heated over 300 F some cements will thicken and will not be satisfactory for use until allowed to cool to the proper temperature range.

Chemical Resistance.

The chemical resistance of plasticized sulfur cements is summarized in Table 2. These cements have excellent resistance to all nonoxidizing inorganic acids and fair resistance to oxidizing acids such as dilute nitric and chromic acids. Sulfur cements are

TABLE 4

Working Time for Cements—Minutes

	60 F	70 F	80 F	90 F
Phenolic	180	60	30	15
Furan	90	60	30	15
Silicate	90	45	30	10

Setting Time for Cements—Hours

	60 F	70 F	80 F	90 F
Phenolic	240	168	120	72
Furan	72	24	15	8
Silicate	96	48	24	16

Note—Chemical resistance is not dependent upon development of final set and in some instances it may be satisfactory to place vessel in service before indicated setting time has elapsed.

attacked by alkaline solutions. Even mild alkalies such as sodium bicarbonate will have some effect at high temperatures. Resistance to organic solvents is poor except with very polar materials such as methanol, ethanol and glycol. Neutral or acidic salts have no effect on sulfur cements, but metallic sulfides may be formed during electrolytic processes. In general, sulfur cements are not recommended for lining electroplating tanks.

The strength properties of sulfur cements will vary considerably with the degree of plasticization of the sulfur cements. The properties given in Table 3 pertain to a cement ideally compounded for use in joining acid-proof brick in tank linings and floors.

Sulfur undergoes a crystalline change from the rhombic form to the monoclinic form at 203 F. As this change is accompanied by a considerable volume expansion, sulfur cement should never be used above this temperature.

A method of dual construction has been developed to permit the use of the relatively inexpensive sulfur cements at temperatures higher than 200 F. In this method two courses of brick are used. The inner course (next to the tank wall) is joined with sulfur cement and the outer one with a resin or silicate cement.

Silicate Cements

Silicate cements are probably the oldest types of chemical resistant cements in use in the chemical industry. They were first used more than 30 years ago in Germany. This type of cement consists of a solution of sodium or potassium silicate and an inert filler, usually graded silica. Older type cements set by the evaporation of water, the setting action being very slow, especially if large masses of material were involved. The newer types contain a chemical setting agent which greatly accelerates setting. These cements are supplied as two-package systems similar to the resin cements described earlier.

Resistance

Silicate cements are not attacked chemically by acids, oxidizing or nonoxidizing, at temperatures up to the vitrification point. Permeability in the presence of acids is lower than with pure water but great enough so that corrosion resistant membranes must be used on any steel or concrete vessel behind the brickwork. Solutions of any degree of alkalinity above pH 7 attack most silicate cements rapidly and should not be used. Organic materials not alkaline in nature have little effect upon silicate cements in the absence of water. Silicate cements are eroded readily by steam and turbulent liquids. In general, this cement is recommended for services at temperatures beyond the range of resin or sulfur cements. Examples of such uses are in the concentration of nitric, chromic, or sulfuric acids at temperatures above 350 F.

Typical chemical setting silicate cements consist of sodium silicate solutions having a specific gravity of 38 degrees Baume and an $Na_2O:SiO_2$ ratio of 1:3.25. The powder consists of a graded silica filler with a small amount of a setting agent such as sodium silicofluoride. The exact nature of the action of the setting agent is not known, but presumably acid is released to form an insoluble silica gel which bonds the filler particles together. Water introduced with the silicate solution evaporates slowly over a long period, leaving a somewhat porous structure.

Working life and setting time of typical commercial silicate cements, as determined by ASTM Method C-308-53T are shown in Table 4.

Masonry Linings

Chemical resistant brick linings are used in conjunction with membrane linings in tanks to

1. Act as a barrier to reduce the temperature at the membrane to a desired or safe maximum,
2. Prevent mechanical damage to the membrane liner, and
3. Permit use of a membrane liner that otherwise would deteriorate due to free access of the chemicals.

Chemical resistant brick linings are used occasionally without a membrane liner between the shell and brick, but this construction requires very close attention to detail and installation and usually is limited to services where temperature changes are small and chemical attack by solution is slow.

Varying temperatures in brick linings cause stresses that may result in fracture and ultimate failure. Careful consideration should be given to lining design. The strongest and most durable construction generally is obtained by using the largest dense form-fitting brick shapes available joined with the most stable and chemical resistant cement for the chemical and physical conditions involved.

The exact design or size of the unit, coupled with the type of cement selected for the service conditions involved will determine the most logical method for installation of the acid brick sheathing. Generally, in a two-course lining the first course is installed in the bottom over the membrane, then the two courses on the walls are installed and the second course on the floor is installed last. This not only keys in the wall lining with the floor, but prevents damage to the finish course on the floor which is installed last and not subject therefore to mechanical abuse during installation of the wall linings.

In many cases, for purposes of economy, a hot-poured sulfur base cement is used in the backing course of brick and a mortar type resinous or silicate cement is used in the face course lining. This enables the completed structure to withstand temperatures in excess of the normal limiting temperature for the hot-poured sulfur cement alone because it is protected by the insulation afforded by the inside or face course lining. This same dual type construction can be utilized with a single course of brick. For purposes of economy, the side joints are laid with a mortar type of cement and the back joint, or the joint between the membrane and the brickwork, is left void until a complete ring is installed around the perimeter. The open joint in the back is filled with the hot-poured sulfur type of cement.

Jointing Technique

It is desirable to hold thickness of cement joints to a practical minimum that will provide full and

continuous joints. Actual thickness will vary, depending upon type of brick and cement, the shape of the brick and to some extent the design of the lining. The joint surface of the brick should be scored to provide maximum strength where sulfur cements are to be used. Brick linings should be self-supporting structures and should be separated from the vessel shell by an impervious membrane lining. It is desirable that the membrane lining be bonded to the vessel shell. In general, adhesion of cements to membrane linings is desirable except where linear expansion of brick is appreciable and damage to membrane is possible. Precaution should be taken where resin cements against elastomer linings are used in long rectangular tanks in hot services.

It is desirable frequently to use expansion joints in the masonry lining in large tanks. If the tanks operate at high temperatures, expansion joints always should be considered. Installation of expansion joints is more of an art than a science and the matter should be reviewed with established vendors.

Temperature drop through the brick in a lined steel tank depends on the temperature gradient between the atmosphere and the process temperature and the total thickness of the brick lining. This is subject to calculation. A rule of thumb allowance of 15 F per inch of thickness of fire clay or shale type bricks and 10 F per inch of thicknes of carbon brick has been found adequate for design purposes for process temperatures up to about 400 F. Temperature drop through the brick in a lined concrete tank will be somewhat less due to the insulating effect of the concrete shell. In almost all instances total thickness of brick used should be sufficient to limit temperature at the membrane lining interface to 150 F maximum. In some services even lower temperatures may be desirable.

Plastic Fireclay Brick

The most widely used acid-proof brick is a buff-colored brick manufactured from plastic fireclays. These clays are primarily siliceous kaolins or "soft clays." They are easily formed and have a high bond strength. They are mixed with semi-flint clays to improve temperature resistance and with calcined clays, or "grog," to control shrinkage during drying and firing. Typical chemical analysis of plastic fireclay acid-proof brick is as follows:

	Percent
Silica	62
Alumina	30
Iron oxides and titania	4
Lime and magnesia	1
Alkalies	2

These brick are burned to vitrification at a temperature of about 2250 F. During firing, the clays are converted to stable minerals which are insoluble in most acids except hydrofluoric. Typical physical properties of press molded plastic fireclay acid-proof brick are as follows:

Cold crushing strength	12,500 psi
Modulus of rupture	3,000 psi
Water absorption (212 F)	2.3%
Apparent Porosity	4.8%

Acid-proof brick are manufactured by three different methods, namely, hand forming, extrusion and press molding. Hand forming is generally confined to large or intricate shapes where the quantity does not justify the use of expensive molds or dies. The clays are mixed in a wet pan called a muller to which water can be added to temper as well as mix materials. The mix is hand worked to approximate the size and shape desired and then forced into a wooden mold, tamped and the excess cut off. The shape, as it is removed from the mold, will contain about 17 percent water. Porosity and permeability of hand formed shapes is greater than that of extruded and pressed shapes and in some instances their over-all serviceability is inferior.

Extrusion or "stiff-mud" method makes use of clays which are first ground in a dry pan, then tempered in a pug mill. The plastic mass is forced through an auger into a deairing chamber which is maintained under vacuum. This operation increases the density and over-all toughness and strength of the finished product.

Another auger forces the material through a die as a continuous column which is wire-cut to the desired size. The brick can be repressed if a smooth surface, sharp corners or a brand name is required. These "green" brick contain about 12 percent water.

The power press molding operation utilizes material from a dry pan mixer which is screened, then tempered with water. This moist mix is first deaired under vacuum then mechanically pressed to shape under a pressure of about 8000 psi. In this operation the moisture content is reduced to about 7 percent. This method produces a brick highly resistant to spalling, hot flow and acid permeation.

The brick formed by each of these methods must be dried and then fired or "burned" to effect the necessary chemical changes in the raw materials required for acid-proof brick.

The most widely used size of fireclay acid-proof brick is the 9 x 4½ x 2½-inch series. Also in common use are the 9 x 4½ x 3-inch series, the 8 x 3¾ x 2¼-inch series and the 9 x 6 x 3-inch series. Each series has a complete range of shapes, including standards, arches, wedges, splits, soaps, keys, circles, neck brick, feather edge brick and skew brick. Also available are special shapes such as 8 x 3¾ x 4½-inch doubles, 12 x 6 x 1½-inch tile, 9 x 4½ x 2½-inch universal circle brick, and 9 x 6 x 2-inch book tile. Usually, these brick are supplied with smooth or wirecut faces, depending on the method of manufacture. They can be scored as a special operation when required. Details of the many sizes and shapes are shown in vendors' brochures for these products.

Red Shale Brick

Another widely used type of acid-proof brick is the red shale brick. These brick are manufactured from shale, which is a clay with a fissile structure, by firing in an oxidizing atmosphere. Basically, these brick fall into two definite types as determined by the preparation of the clay prior to forming.

All shale brick are made from unblended clays, therefore, the exact composition varies from one

maker to another as well as with the same producer over a period of time. The first type is manufactured from washed and screened clays. These brick are of the same high quality as building face brick.

Typical chemical analysis of red shale acid-proof brick is (percent): Iron oxides 8, silica 65, alumina and titania 18, lime and magnesia 2, alkalies 3, combined water 4.

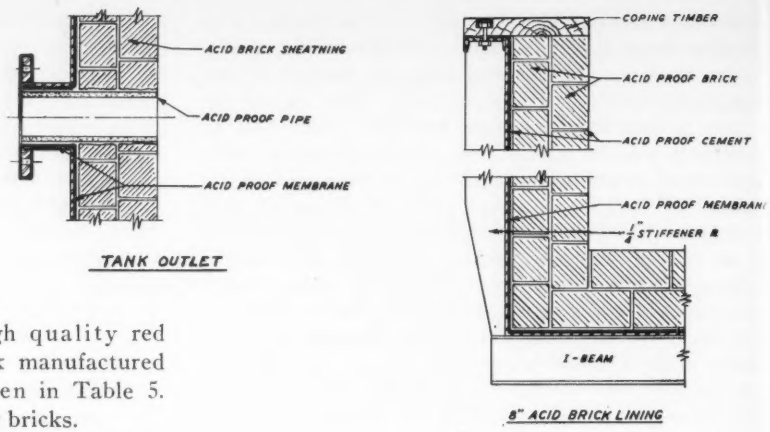

Figure 1

Typical physical properties of high quality red shale acid proof brick and of brick manufactured from raw clay "as mined" are given in Table 5. These latter are similar to red paving bricks.

Practically all red shale brick are made by the "stiff mud" method. The shale is tempered with water to the proper plasticity in a mixer. It is then deaired, extruded and wire-cut to the desired size. These brick usually are not repressed although they can be scored or textured to increase the cement bond. The "green" brick are dried to the proper moisture content, then they are fired in an oxidizing atmosphere. Normally, the firing is carried out in a circular down-draft kiln together with face brick or paving brick. The acid brick are placed in the top of the kiln where the temperature reaches 2000 F. The kiln is held at the maximum temperature for a period from 24 to 60 hours in order to thoroughly vitrify the brick and eliminate "soft centers."

Shale brick are thoroughly vitrified, relatively hard and resistant to abrasion and erosion. They are not as resistant to thermal shock as the plastic fireclay type acid-proof brick. Shale brick vary in color from dark brown to deep red.

Principal uses for red shale acid-proof brick are for acid tank linings and for floors. An 8 x 3¾ x 2¼-inch, 9 x 4½ x 2½-inch, or 8½ x 5 x 3¾-inch series is used commonly for sheathing acid pickling tanks. In this service, resistance to mechanical impact is as much a factor as inertness to hot sulfuric acid. It is customary to use a double brick (8 x 3¾ x 4½-inch or 9 x 4½ x 5-inch) in such installations in order to conserve cement. These brick usually are scored on five sides when a sulfur-based cement is used for the bonding mortar. Whenever a resin-based cement mortar is used, the brick normally are wire-cut on five sides. Other finishes commonly available are smooth, wire-cut on three sides, or textured on three sides.

Two ASTM specifications give additional information on acid-proof brick. These are C 279-54 on Chemical Resistant Masonry Units and C 67-50 on Methods of Sampling and Testing Brick.

Carbon brick are made from granular carbon particles which are mixed and compressed with a pitch binder and then fired at high temperatures to provide structurally strong material. The various brick shapes available are cut from larger pieces formed during production of this grade of carbon. Graphite brick are available also. These have higher thermal conductivity and resistance to oxidation but are somewhat softer. Carbon brick are used generally in preference to graphite brick because of the higher thermal conductivity and lower hardness and resistance to abrasion of the graphite.

Carbon and graphite brick are chemically resistant to all acids, alkalies and solvents with the exception of a few strong oxidizing agents. They are appreciably higher in cost than the fire clay and shale materials and their use is limited generally to applications involving hydrofluoric acid or strong alkalies.

Compressive strength of carbon brick is about 6000 psi and its modulus of rupture about 3000 psi.

Typical lining details for a double course brick and membrane lined open top steel tank are shown in Figure 1. Where desirable, tanks can be closed at the top by covers made of wood, plastic, membrane-covered steel, alloy steels or other materials. For severe conditions brick linings can be extended and installed as tank tops as domes or arches.

Costs

Approximate cost as of March, 1956, for component parts of membrane and brick-lined vessels of medium size are summarized in Table 6. Generally, cost of small tanks (less than 200 sq. ft.) will be somewhat greater and the cost for larger tanks (over 1000 sq. ft.) may be less.

Total cost for vessels with selected membrane linings and combinations of brick shapes and cements may be estimated by adding the respective costs for the selected types of construction. The cost data represent average costs for linings applied in or near the vendor's shop. Where field application is required, the cost may be greater by a factor of 10-20 percent, depending on traveling and living expenses for the lining crews.

TABLE 5—Red Shale Acid Proof Brick

Physical Properties	High Quality	"As Mined" Paving
Cold Crushing Strength	19,700 psi	11,500 psi
Modulus of Rupture	3,130 psi	2,770 psi
Water Absorption, 212 F	1.8%	1.2%
Apparent Porosity	3.8%	2.4%

TABLE 6—Cost Data for Brick-Lined Vessels

TANKS

Steel—Flat bottom, open top, one outlet nozzle.....15-18 cents/lb.
ASME heads, manhole and two nozzles.....18-20 cents/lb.
(¼-inch thick steel weigh approximately 10 lb./sq. ft.)
Concrete—8-inch wall and double pattern of steel reinforcement.....$75-$125 per cu. yd.

Membrane Linings	Thickness Inches	Installed Costs $/ft.[2]
Natural Rubber	3/16	3.40
	¼	3.80
Neoprene	3/16	3.50
	¼	3.95
Plasticized Polyvinyl Chloride	3/32	4.00
Lead Sheet	⅛	2.75
	3/16	4.00
Hot Mastic (concrete only)	¼	1.00

Brick Linings	Fire Clay and Shale		Carbon	
	1 Course 4" Thick	2 Courses 8" Thick	1 Course 4½" Thick	2 Courses 9 Thick
All Sulfur Cement	$3.50	$7.00	$12.50	$24.00
All Silicate	3.50	7.00	.....	.....
Modified-Back Joint Sulfur, Side Joints Resin	3.75	7.50	.....	.....
All Resin	4.00	8.00	13.00	26.00

First Interim Report

Publication No. 57-7

Suggested Painting Specifications for Marine Environments

NACE Technical Unit Committee T-1M on Corrosion of Oil and Gas Well Producing Equipment In Offshore Installations*

Prepared by Task Group T-1M-2 on Protective Barriers*

Abstract

Specifications and recommendations are given significant to contractors and operators applying and purchasing coatings systems in marine environments. The recommendations cover equipment, surface preparation, specific coatings systems, inspections and the techniques related to these items. 5.4.8

UNIT COMMITTEE T-1M was organized in March 1955 to attempt reduction of the mushrooming cost of controlling corrosion of oil and gas well producing equipment in offshore installations. In 1955 the investment in equipment and installations of offshore drilling operations in the Gulf of Mexico exceeded $150 million. In that year over $2 million was paid out for protective coatings on platforms alone.

The committee is working on ways to raise the quality of protective coating application. As part of this work Task Group T-1M-2 was assigned to investigate protective barriers. This report, prepared by the task group, is a composite of phrases drawn from offshore operators' specifications and other sources. From this composite a user may take phrases that suit his purposes best.

Use of specific detailed specifications and inspection by qualified inspectors has proved valuable in assuring protection with long life.

1.0 SCOPE

1.1 These specifications are general and apply to some degree to all air drying coatings regardless of generic type. When generic types are referred to later applicable specific portions of this general specification will be referred to by numbers.

1.2 These specifications cover the procedure required for various types of surface preparation, application and inspection for major equipment used in offshore oil and gas production.

1.3 The contractor shall furnish all labor, material and equipment to properly prepare the surface and paint in accordance with the following schedule. (Note: Some operators prefer to furnish the coating materials and contract the application. This is done to assure that right materials, without substitution, are used on the job.)

1.4 The company for whom the work is being done hereinafter will be referred to as the operator.

1.5 All work and application procedures under these specifications or within the intent of the specifications, shall be subject to inspection by the operator's engineers and/or inspectors so designated by the operator. All defective work or work not conforming to specifications shall be repaired at no additional cost to the operator.

1.6 The operator's engineer or inspector shall be given at least two days' notice prior to initiation of any work covered by these specifications. While work is in progress the inspector shall be given at least four hours' notice of any changes in schedule. All points of work shall be accessible to the inspector. No surface preparation and/or coating application shall be done in the absence of the inspector without his knowledge or consent.

1.7 All equipment specified in contractor's bid as available and to be used on contract under consideration and such additional equipment required by these specifications will be subject to inspection before work starts under contract. If in the opinion of the operator's inspector, any of this equipment is found unsuitable to the extent it would interfere with desired results before or after work starts, work will not begin.

1.8 All contractor's personnel involved in contract under consideration will be thoroughly familiarized as to the materials and specifications pertaining to the contract before work begins. If contractor's personnel are not familiar with the materials and techniques herein specified, a meeting shall be held and attended by all contractor's personnel involved under considered contract before beginning work. The operator's inspector will explain to and instruct said personnel in all of the materials and requirements of this contract. Contractor will have one or more copies of the specifications. He is expected to have studied the specifications and understand all procedures, etc.

1.9 The contractor will be responsible for keeping daily progress and inspection reports. These forms will be supplied by the operator. The contractor must obtain written approval from the operator's representative after each step of surface preparation and before each coating application.

1.10 Scaffolding or staging will be used for surface preparation and painting and will be subject to approval of the operator's inspector. It shall be such that easy and sufficient access will be provided for correct painting of all surfaces. It shall be such that operators will be able to stand up with body and arms free of scaffolding or staging and structure being worked on. It shall be provided with safety features that will help to prevent accidents.

1.11 All contractors are expected to have equipment adequate to conform with these specifications.

1.12 On floating marine equipment the entire exterior surface shall receive the same surface preparation and coating system as specified. This is to include areas resting on support blocks.

2.0 SURFACE PREPARATION—GENERAL

2.1 Surface Preparation by Sandblasting—General

2.1.1 Sandblasting shall be performed by experienced operators with approved equipment.

2.1.2 All welded areas and appurtenances shall be given special attention for removal of welding flux in crevices. Welding splatter, slivers, laminations and underlying mill scale not removed during fabrication and exposed before and during sandblasting operation shall be removed by best mechanical means and edges smoothed or rendered flush.

2.1.3 The compressed air supply used for blasting shall be free of detrimental amounts of water and oil. Adequate separators and traps shall be provided and these shall be kept emptied of water and oil. Low temperature produced compressed air is desired. In no case will air compressors be allowed to work in excess of 240 F. Accumulations of oil and moisture shall be removed regularly from the air storage tank by opening petcock at bottom of the tank.

2.1.4 Blast cleaning operations shall not be conducted on surfaces that will be wet after blasting and before painting, or when the surfaces are less than 5 F above the dew point or when the relative humidity of the air is greater than 80 percent. (Some specify 85 percent.) (See item 4.0.3.)

2.1.5 The blast cleaned surface shall be coated with pretreatment material and one coat of primer as specified during the same day as blasted and prior to sundown of that day and also before any

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visible rusting occurs. A minimum of 4 inches around edge of sandblasted areas will be left uncoated unless adjoining a coated surface. Sandblasting shall continue a minimum of 1 inch into adjoining coated surface. Any steel not primed or any wet by rain or moisture shall be reblasted if any rust develops.

2.1.6 All fabrication shall be complete in final condition before surface preparation begins. Exception of this procedure shall be determined by the operator's inspector or corrosion engineer.

2.1.7 Sandblasting shall not be done in areas close to painting operations and wet coated surfaces to prevent dust and sand contamination.

2.1.8 Only hard silica or flint type sand should be used.

2.1.9 The grit shall be 30 to 50-mesh abrasive to be discharged from a 5/16 inch nozzle at 100 pounds pressure. It is suggested that the nozzle distance from the steel surface be 6 to 12 inches. The maximum particle size may be no larger than that passing through a 30-mesh screen, U. S. Sieve Series. The mesh may be 15 to 20 if removing old coatings or thick rust scale. The height of the anchor profile should not exceed 2 mils unless approved by the operator. This will be as outlined in Reference 1. Blast materials containing impurities or inclusions will not be used. Some specify that the height of profile of the anchor pattern produced on the surface shall be limited to a maximum of 1/3 of the total dry film thickness of the coating to be applied.

2.1.10 Sandblasting shall be permitted only during the daylight hours except that rough sandblasting will be allowed during the night in the absence of the inspector, providing the surface shall be swept clean and bright the next morning with a fresh light sandblasting.

2.1.11 The sandblasted surface shall be rendered dust free prior to the application of pretreatment material or prime coat. This can be accomplished by blowing off the surface with clean dry air or preferably by using an industrial vacuum cleaner.

2.1.12 All bolt holes shall be drilled prior to sandblasting.

2.1.13 No acid washes or other cleaning solutions or solvents shall be used on metal surfaces after they are sandblasted. This includes inhibitive washes intended to prevent rusting.

2.1.14 All oil and/or grease contamination shall be removed by solvent washing or other suitable means before starting to sandblast.

2.1.15 Maximum speed and most effective cleaning is obtained by systematic, even blasting. Block out work in one foot squares and blast each square evenly until complete.

2.1.16 The sandblasted surfaces shall be examined for traces of smudges, oil or grease. If any exist, they shall be removed by solvent washing and the area re-sandblasted.

2.2 Sandblasting—White Surface Finish

This specification requires that all steel surfaces to be coated shall be cleaned to "white" metal at gray white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coating. The surface when viewed without magnification shall be found free of visible mill scale, rust, corrosion, oxides, paint, oil, or other foreign matter. This surface shall be cleaned as specified in Reference 2.

2.3 Sandblasting—Commercial Surface Finish

This specification requires the removal of all scale, rust, rust scale, paint, oil, or other foreign material, but does not require the complete removal of the gray mill scale binder existing between the mill scale and steel. A commercial surface blast will produce a surface that is fairly uniform gray with a streaky color to the naked eye. This specification is further expressed and qualified in Reference 3.

2.4 Sandblasting—Brush Off Blast Cleaning (Sand Washing)

This specification requires the removal of all loose mill scale, slag, loose rust and loose paint as further specified in Reference 4.

2.5 Surface Preparation by Hand Cleaning and Power Tool Cleaning

This specification requires the removal of all loose mill scale, rust, paint and detrimental foreign matter, as further specified in Reference 5.

2.6 Surface Preparation by Solvent Cleaning

This specification shall be used with other specified surface preparations when necessary for removing detrimental foreign matter such as oil, grease, soil, paint and contaminants. This specification is further expressed and specified in Reference 6.

2.7 Zinc Coated Surfaces

All galvanized surfaces to be painted shall receive the above solvent cleaning. If the manufacturer of the coating being used recommends additional surface preparation its recommendations shall be followed. Galvanized surfaces, as will any surface to be painted, shall be free of dirt or other foreign material.

2.8 Flame Cleaning and Wire Brushing

Flame cleaning and wire brushing have been used prior to application of protective coatings to bare steel or welded surfaces in the Gulf of Mexico. The exposed steel shall be flame cleaned and wire brushed and the coating applied while the steel is still warm.

3.0 COATING MATERIALS

3.1 All coating material or paints will be furnished in unopened containers and shall be so labeled as to identify them as material specified for the job.

3.2 All coating material shall be boxed and vigorously stirred for a time sufficient to thoroughly mix again the pigments and vehicles.

3.3 Only thinners specified by the manufacturer shall be used.

3.4 Mixing and thinning directions as furnished by the manufacturer shall be followed unless modified by the inspector. Changes made by the inspector shall not create a mixture more difficult to handle and apply.

3.5 If coating material requires the addition of a catalyst, the pot life under application conditions shall be clearly stated on the label. This pot life must not be exceeded by the contractor. When the pot life limit is reached the spray pot must be emptied, material destroyed, equipment cleaned and new material catalyzed.

3.6 Paint which has livered, gelled, or otherwise deteriorated during storage shall not be used; thixotropic materials which may be stirred to obtain normal consistency are satisfactory.

3.7 Coatings containing heavy or metallic pigments that have a tendency to settle must be kept in suspension in the pressure pot by a mechanical stirrer.

4.0 APPLICATION—GENERAL

4.0.1 The surface must be clean, free from dust, sand and be dry before priming or application of any coat of paint.

4.0.2 No coating shall be applied during fog, mist or rain.

4.0.3 No coating shall be applied to any surface showing moisture discernible with the eye and touch by the following test for condensation:

If it is suspected that temperature and humidity conditions are such that moisture is condensing upon the surface, the latter shall be moistened with a damp cloth to apply a clearly defined thin film of water. If this film evaporates and decreases after 15 minutes, the surface shall be considered safe to paint from the standpoint of continued condensation at that particular time. Others specify that no coating be applied when relative humidity is above 80 percent. No coating shall be applied at air temperatures below (some specify 40 F, others specify 50 F), nor when there is likelihood of change in weather conditions within two hours after application which would result in air temperatures below those specified, or deposition of moisture in the form of rain, snow, condensation, etc. upon the surface. The inspector reserves the right to stop the application of paint when, in his opinion, weather conditions may result in injury to the applied coating.

4.0.4 Each coating shall be allowed to dry thoroughly and/or allowed to dry the specified time prior to application of a succeeding coat.

4.0.5 No coating shall be put on edges prepared for field welds or within six inches of these edges.

4.0.6 Painting will not be allowed over sandblasted areas six inches away from the unblasted areas.

4.0.7 All coating film thicknesses must be adhered to strictly. These film thicknesses are to be checked by the inspector with a calibrated film thickness gauge. Where film thicknesses do not meet specifications, additional material shall be applied at no additional cost to the operator. The film thickness gauge should be calibrated in the film thickness range being checked and over the type of surface being coated. One method of accomplishing this is to place the known standard (of the desired thickness) over the prepared surface and set the gauge dial at the mil thickness of the standard. In cases of dispute or doubt, a section of the film can be removed and checked with a micrometer caliper.

4.0.8 The completed coating system shall be free of defects such as pinholes, voids, bubbles or other "holidays." This will be checked by the inspector with a suitable low voltage paint film holiday detector. Defects shall be marked with a compatible coating. Any areas failing to meet this test shall receive additional coats until they pass the test. These additional coats shall be applied at no additional cost to the operator.

4.0.9 Prior to application of any coat of material all damage to previous coats shall be touched up with corresponding specified coating. Damage prior to delivery to finish coating shall be reprimed and refinished.

4.0.10 The sequence to be followed in painting will be such that a minimum of damage to finished coatings will result.
4.0.11 The first coat of specified primer shall be brushed on all welds, crevices, corners and areas inaccessible to spray.
4.0.12 Some manufacturers recommend that the entire prime coat be brush applied. Where this is the case these recommendations must be adhered to.
4.0.13 Each coat is to be applied uniformly and completely over the entire surface. Skimps, skips, sags and drips are to be avoided.

4.1 *Spray Application*

4.1.1 All equipment must be inspected and approved by the inspector before any application is begun. Lines and pot must be clean before adding new material.
4.1.2 An adequate moisture trap shall be placed between air supply and pressure-pot pressure feed to gun. Trap will continually bleed off any water or oil from air supply.
4.1.3 Suitable and working regulators and gauges will be provided for both air supply to pressure pot and air supply to pressure gun.
4.1.4 The spray gun shall be held no closer than 6 inches or more than 8 inches from surface to be coated and shall always be held at right angles to the surface. Even, parallel passes should be made with the spray gun.
4.1.5 Fluid pressure shall be maintained and regulated to deliver not more than 24 ounces per minute of material from spray gun.
4.1.6 Air shall be regulated to the minimum amount required to properly atomize the material.
4.1.7 Spray width adjustment on gun will be made and readjustment of atomizing pressure at regulators will be made until desired spray pattern is found.
4.1.8 In application of material, each spray pass shall overlap the previous spray by 50 percent.
4.1.9 Large surfaces always shall receive passes in two directions at right angles to each other (cross-hatched). This procedure is sometimes referred to as multipass coating.
4.1.10 To avoid unnecessary overspray, spraying of paints from single boatswain's chair or spider stage will not be permitted except where no other means is possible.
4.1.11 Spray application shall be performed by experienced operators who are familiar with the contents of booklets listed in Reference 7 or their equivalent.
4.1.12 Better results are obtained if the pressure pot is kept at approximately the same elevation as the spray gun.
4.1.13 All runs and sags shall be brushed out immediately or the paint shall be removed and the surface resprayed.
4.1.14 In spray painting it is desirable to obtain a full, uniform wet coat of paint, of sufficient film thickness and free of holidays.

4.2 *Brush Application*

4.2.1 Brushes shall be of a style and quality that will permit proper application of paint. Round or oval brushes generally are considered most suitable for rivets, bolts, irregular surfaces and rough or pitted steel. Wide flat brushes are suitable for large flat areas, but they should not have a width of over (some specify 4 inches, some 5 inches). No extending handles shall be allowed on paint brushes.
4.2.2 The brushing shall be done so that a smooth coat, as nearly uniform in thickness as possible is obtained. There should be no deep or detrimental brush marks.
4.2.3 Paint shall be worked into all crevices and corners.
4.2.4 Runs or sags shall be brushed out.
4.2.5 In brushing any of the solvent type coatings, care must be taken so that no lifting of former coats occurs.
4.2.6 Surfaces not accessible to brushes shall be painted by spray, by daubers, or by sheepskins.

4.3 *Roller Coating*

4.3.1 In roller application of solvent type coatings, care must be taken that no lifting of former coats occurs.
4.3.2 Only materials proved adaptable to roller coating should be considered for this type of application.
4.3.3 All welds, rough spots, pits, rivet heads, edges, corners, etc., must have coating brush applied.
4.3.4 Coating is to be applied uniformly and free from holidays, voids, sags, etc. should pass low voltage holiday test like coating applied by any other method.
4.3.5. The maximum length handle allowed on roller is four feet.
4.3.6 The maximum width roller is nine inches if supported at one end and eighteen inches if supported at both ends by a Y connection.

4.4 *Hot Spray Application*

4.4.1 Only materials specially formulated for hot spray application should be considered.
4.4.2 Heavier fluid hoses than for conventional spraying are required.
4.4.3 Hot spraying technique is more demanding than for conventional spraying.
4.4.4 Applicator should be experienced with this type application before being allowed to proceed on any marine equipment.

5.0 INSPECTION

5.1 The operator shall be represented by an inspector to insure conformance with the job specifications. All work done under these specifications shall be subject to inspection.
5.2 All parts of the work shall be accessible to the inspector.
5.3 The inspector shall have the right to inspect at all times any tools, materials, or equipment used or to be used in the performance of the coating application.
5.4 The inspector shall have the right to condemn any and all equipment or work which does not conform to the specifications. Condemned areas will be marked with a compatible paint of contrasting color.
5.5 Defective work or work not conforming to specifications shall be redone by the contractor at no additional cost to the operator.
5.6 Prior to final acceptance a final inspection will be made. Representatives of the contractor and paint manufacturer may be present. Again, defective areas shall be repaired by the contractor at no additional cost to the operator.
5.7 If the inspector is unable to be on the job after reasonable notice has been given, then the contractor may begin work without the inspector.

6.0 GENERIC TYPES OF AIR DRYING COATINGS

6.1 *Vinyls (Conventional)*

6.1.1 All general specifications for marine environment in preceding section apply except that sandblasting to white metal will be the only approved method of surface preparation.
6.1.2 Metal conditioner or other special vinyl primer must be applied over the sandblasted surface as soon as possible and not later than the same day as blasted. If metal conditioner is used, only so much as can be used within an 8-hour period shall be mixed. Any material unused 8 hours after mixing shall be discarded.
6.1.3 The second coat of vinyl sometimes referred to as an anticorrosive coat, also should be applied the same day as blasting.
6.1.4 Vinyl paints shall be applied by spray when practicable, but primers may be brushed. All welds and hard-to-spray areas shall receive a brush coat in addition to the regular spray coat.
6.1.5 In all cases the coat of vinyl being applied shall have a sufficiently different color from preceding coat to permit visual determination of complete coverage.
6.1.6 Sufficient build coats and body coats of vinyl shall be applied so that with the finish coat of approximately 1 mil the entire vinyl system shall have a minimum film thickness of 5 mils. Additional film thickness may be specified if desired. Total number of coats will vary from four to seven, depending upon the film thickness obtained from the vinyl being used.
6.1.7 Prior to application of the finish coat the entire coated area shall be tested with a low voltage holiday detector. Areas not passing the test shall receive additional coats until the test is passed.
6.1.8 After the final coat is applied the surface is checked for film thickness. Areas not conforming to the specified film thickness shall be marked with a vinyl of contrasting color and additional material applied until the desired film thickness is reached.
6.1.9 A drying time of from 2 to 4 hours between vinyl coats is recommended.
6.1.10 Some operators specify one or more coats of copper base vinyl antifouling material to be applied over the anticorrosive coats below water.
6.1.11 A vinyl antiskid coat containing a non-sparking mineral aggregate can be specified on decks or other areas for safety reasons.

6.2 *Vinyls—Mastic*

6.2.1 All general specifications for marine environment preceding apply except that sandblasting to white metal will be the only approved method of surface preparation.
6.2.2 One coat of special inhibitive phosphoric acid type of primer spray must be applied to a film thickness (dry) of 0.75 mil and must be well mixed and kept mixed while spraying. It must be applied the same day as blasting.
6.2.3 One coat (anticorrosive build coat) spray must be applied as soon as solvents have evaported from prime coat but not before one hour after application of primer. It shall be applied by multipass system. Dry film thickness of this coat will be 1.25 mils.

6.2.4 One coat (anticorrosive build coat) same as 8.2.3, except of contrasting color shall be applied. Dry film thickness of this coat will be 1.25 mils.

6.2.5 One coat vinyl mastic will be applied to produce a dry film of 10 mils. This material should be applied with a head assembly[8] using a 3/16 inch opening or equivalent. A thickness of 10 mils should be obtained with two passes of the spray gun, but the number of passes necessary will depend upon the technique of the operator. A thickness of over 10 mils in one application is not desired.

Thinning with recommended solvent 20-25 percent by volume will be necessary.

6.2.6 One finish coat of desired color will be applied with a dried film thickness of 1 mil. Prior to applying the top coat all coated surfaces should be checked with a low voltage holiday detector to insure adequate coverage. Deficiencies will be repaired with the vinyl mastic. The mastic should be allowed to dry overnight (16 to 24 hours) before application of top coat. The finish coat should be applied to obtain complete hiding to make a seal over the mastic.

6.2.7 Total final film thickness of all coats should be in excess of 14 mils. One operator specifies for the tidal area that the mastic coat be applied to a total dry film thickness of 20 mils, but not in one application. This would give a complete system with a minimum of 25-26 mils.

6.3 *Activated Epoxy System*

6.3.1 All of general specifications for marine environment preceding apply except that the sandblasting to white metal is the only approved method of surface preparation.

6.3.2 All blasted surfaces shall be primed the same day by spraying with two coats of specified primer. A dry film thickness of 2 to 2.5 mils per coat is recommended.

6.3.3 Pot life shall not exceed 8 hours. (See 3.5.)

6.3.4 It is very important to follow manufacturer's directions as to the addition of the catalyst and thinners. Mixing directions should be adhered to strictly.

6.3.5 Drying time of 2 to 3 hours between coats is recommended.

6.3.6 Two finish coats are sprayed over the primer. A dry film thickness of 2 to 2.5 mils per coat is recommended.

6.3.7 The film thickness of the finished job shall not be less than 8 mils for all coats.

6.3.8 Before the final coat is applied, paint thickness and low voltage "holiday" detection surveys will be made and deficiencies will be corrected before the final coat is applied.

6.3.9 Some operators specify a minimum of 13 mils on overall structure and 16 mils on the weld areas or other rough and hard to protect points. A brush coat of mastic is recommended over these latter areas prior to final coat.

6.4 *Conventional Marine Paints*

6.4.1 The majority of the items in the general specifications apply, the main exceptions being in surface preparation. Some operators specify that this type coating be applied over solvent and mechanically cleaned surfaces. Others recommend a dilute phosphoric acid treatment or the application of a vinyl metal conditioner over galvanized metal surfaces. Other operators specify better surface preparation.

6.4.2 No more surface preparation shall be done in any day than can be painted that day.

6.4.3 Item 3.5 regarding pot life does not apply to marine paints.

6.4.4 Operator should specify type of application: Spray, brush or roller.

6.4.5 Ordinarily a minimum of 2 prime coats and 2 finish coats are specified for marine environment.

6.4.6 A film thickness of from 4 to 5 mils is recommended.

6.4.7 Drying time between coats shall conform with manufacturer's recommendations.

6.4.8 Surfaces which have been painted shall not be worked on or otherwise disturbed until the previous coat is completely dry and hard.

6.4.9 All surface coatings and paint applications shall be guaranteed for a period of 90 days following final application and touch up.

6.5 *Coal Tar Cut Back (Thixotropic)*

6.5.1 To be applied to all galvanized or metallized beams. Top skid beams to be ground smooth at welds prior to metallizing with 10 mils of zinc.

6.5.2 Galvanized surfaces are to be solvent cleaned and brushed to remove weld splatter, dirt or other foreign material.

6.5.3 Coating material is not to be thinned; stirring alone will effect a reduction in viscosity.

6.5.4 Welds that have been thoroughly cleaned and received a brush coat of the coal tar paint should be allowed to dry at least 24 hours before receiving a spray coat of the material.

6.5.5 Applicable items from the general specifications for marine environment pertaining to surface preparation or coating application may be used to assure the work being done in a workmanlike manner.

6.5.6 Coal tar coating appears to be more temperature sensitive than other coatings, so temperature and moisture conditions at time of application should be favorable.

6.5.7 Coal tar coating is to be sprayed at a rate giving a coverage of from 55 to 70 sq. ft./gallon. This will provide a dried film thickness of about 20 mils.

6.6 *Coal Tar Emulsion*

6.6.1 This type material is to be used above elevation plus 15 mean Gulf level.

6.6.2 This material is not recommended and ordinarily is not used alone as a protective coating.

6.6.3 Coal tar emulsion is ordinarily used in conjunction with coal tar cut back coatings to prevent weathering, checking, cracking, etc.

6.6.4 Between elevation plus 15 and plus 5 MGL, two shop coats and one field coat of applied coal tar emulsion is to be applied to a total thickness of 1/8 inch over a 1/8 inch coating of cold applied coal tar cut back (6.5).

6.6.5 This material must be protected from freezing.

6.6.6 Manufacturers' specifications and directions are to be followed as to mixing, application, etc.

6.7 *Chlorinated Rubber, Neoprene and Other Special Coatings*

6.7.1 Material of this class was not covered by operators but if such materials are to be used, most of the items outlined in 6.1 would apply.

6.8 *Inorganic—Zinc Based Paint*

6.8.1 Manufacturer's specifications as to surface preparation, mixing, application and curing are to be followed.

6.8.2 Appropriate items in the general specifications for marine environments may be used to augment those supplied by the manufacturer.

6.9 *Metallizing*

6.9.1 All items under the general specifications for marine environment pertaining to the sandblasting of the metal surface and the specifications for blasting to white metal apply to metallizing.

6.9.2 Metallizing will be done by experienced operators using specified metal and applying it to the desired uniform film thickness.

6.9.3 Metallized surface will be sealed with either a chlorinated rubber system or a vinyl system.

6.9.4 Sealing should follow metallizing as soon as practicable.

6.10 *Tapes*

6.10.1 Polyvinyl and polyethylene tapes are specified for use over tubular rails, control lines, etc. both in conjunction with other coatings and over clean specially primed surfaces.

References

1. SSPC-SP-5-52T (3.9). Steel Structures Painting Council, 4400 Forbes Avenue, Pittsburgh, Pennsylvania.
2. SSPC-SP-5-52t, "Blast Cleaning to White Metal." Steel Structures Painting Council.
3. SSPC-SP-6-52t, "Commercial Blast Cleaning." Steel Structures Painting Council.
4. SSPC-SP-7-52t, "Brush Off Blast Cleaning." Steel Structures Painting Council.
5. SSPC-SP-3-52t, "Power Tool Cleaning," and SSPC-SP-2-52t, "Hand Cleaning." Steel Structures Painting Council.
6. SSPC-SP-1-52t, "Solvent Cleaning." Steel Structures Painting Council.
7. "The ABC's of Spray Equipment" (F-278) and "Spray Gun Motion" (F-275), DeVilbiss Company, Toledo 1, Ohio.
8. DeVilbiss head assembly 326 or equivalent.

Second Interim Report

Publication No. 57-8

Suggested Coating Specifications for Hot Application of Coal Tar Enamel For Marine Environments

NACE Technical Unit Committee T-1M on Corrosion of Oil and Gas Well Producing Equipment In Offshore Installations*

*Prepared by Task Group T-1M-2 on Protective Barriers***

Abstract

Specifications and recommendations are given significant to contractors and operators applying and purchasing coal tar coatings systems in marine environments. Recommendations cover surface preparation, materials and systems, handling of material, application and inspection. 5.4.8

1.0 SCOPE

1.1 These specifications apply to the application of coal tar enamel in the molten condition, either with conventional pipe line coating equipment or on flat surfaces with hand daubers.

1.2 These specifications cover the procedure required for surface preparation, application and inspection of hot applied coal tar enamel systems intended for use on offshore drilling and production platforms.

1.3 The contractor shall furnish all labor, material and equipment to prepare the surface and apply the coal tar enamel systems.

1.4 The company for which the work is being done hereinafter will be referred to as the operator.

1.5 All work and application procedures under these specifications or within the intent of these specifications shall be subject to inspection by the operator's engineer or inspector so designated by the operator. All defective work or work not conforming to specifications shall be repaired at no additional cost to the operator.

1.6 The operator's engineer or inspector shall be given at least two days' notice before work covered in these specifications is started. While work is in progress the inspector shall be given at least 4 hours' notice of any change in schedule. All points of work shall be accessible to the inspector. No surface preparation and/or application of hot enamel shall be done in the absence of the inspector without his knowledge or consent.

1.7 Yard coated and wrapped pipe, columns, or other tubular steel treated prior to fabrication shall be that pipe, etc., cleaned, coated and wrapped by a permanently established, experienced company specializing in this type work. This company must have the necessary machinery and equipment for coating all sizes of tubular steel goods encountered.

1.8 All yard coating and on the job repairing of fabricated joints, or hand applied enamel to surfaces other than tubular shall be done in accordance with recommendations as stipulated in standard handbooks relating to these operations.[1, 2, 3, 4]

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** H. E. Waldrip, Gulf Oil Corp., Houston, chairman.

2.0 SURFACE PREPARATION

2.0.1 It should be remembered that the quality of the job, whether hot applied coal tar enamels or air dry coatings are used, is largely dependent upon the type and quality of surface preparation. The type selected below should be specified.

2.1 All metal to be coated with coal tar enamel shall be dry sandblasted or grit blasted according to Reference 5. This is the best type of surface preparation.

2.2 All metal to be coated with coal tar enamel shall be dry sandblasted or grit blasted according to Reference 6. This is the next best type of surface preparation.

2.3 Mechanical cleaning by pipe coating yard shall be done with such mechanical equipment and in such a manner that Reference 7 shall be equalled or exceeded.

2.4 Flame cleaning and wire brushing have been used before application of protective coatings (including coal tar tape) to bare steel or welded surfaces on platforms in the Gulf of Mexico. The exposed steel shall be flame cleaned and wire brushed and the coating applied while the steel is still warm.

3.0 MATERIAL AND SYSTEMS

3.1 Coal tar enamel to be used in coating and wrapping tubular columns, smaller diameter steel tubing for the fabrication of offshore platforms and that used for hand application shall have the following specifications:

3.1.1 The enamel shall be a fully plasticized coal tar enamel having a temperature exposure range from —10 F to +160 F, penetration at 77 F of 4 to 9, and at 115 F a penetration of 12-25, and an ash content of from 25 to 35 percent by weight on ignition.

3.1.2 Coal tar enamel to be used for hand application other than patching shall be free-flowing grade having the same specifications as 3.1.1 except that the ash content shall be from 20 to 25 percent by weight.

3.1.3 Coal tar emulsion is sometimes used over a hand applied hot coal tar enamel job for protection against cracking, weathering, checking, etc. Specifications as to the use of this material are the same as listed under air drying coatings of the same subject.

3.2 *Handling and Heating of Coal Tar Enamel*

3.2.1 Recommendations for the handling of coal tar enamel as listed in standard handbook[1, 2, 3, 4] on materials of this kind shall be observed strictly.

3.2.2. The precautions mentioned herein are necessary for the contracting of hand applied coal tar enamel. (Most pipe coating yards conform to all the recommendations, but the inclusion of these precautions does no harm.)

3.2.3 The enamel shall be chopped into pieces weighing a maximum of 25 lb. The chopping and other handling shall be done in such a manner that there shall be no contamination by dirt, weeds, cinders, grass or other foreign material. The chopped supply shall be kept covered with a tarpaulin or other suitable means when there is danger of contamination.

3.2.4 The melting kettle shall be carefully cleaned of traces of old coatings, coked deposits, oil and other foreign matter.

3.2.5 Covered, mechanically agitated kettles must be used. Thermostatically controlled kettles are preferred. Wooden sticks or paddles shall not be used for stirring the enamel.

3.2.6 Care must be taken in melting the charge. Manufacturer's instructions shall be adhered to strictly.

3.2.7 The enamel must not be overheated.

3.2.8 In case of a temporary shutdown the burners will be lowered immediately and the charge kept at about 100 degrees less than the application temperature recommended by the manufacturer.

3.2.9 Operations should be so judged that a large amount of enamel is not left for reheating. Old charge should not constitute more than 10 percent of the total charge.

3.2.10 Each kettle shall be equipped with an accurate and easily read thermometer. The temperature of the enamel shall be checked every 15 minutes. The enamel shall be held at the specified temperature during application. Enamel heated to temperatures above that specified for more than a few minutes or heated for prolonged periods without agitation and/or with open lids shall be condemned and dumped. The kettle shall be recleaned before recharging. Kettle thermometer shall be checked periodically for accuracy with a long stemmed mercury thermometer.

3.3 The proper grade of coal tar primer shall be used with the hot coal tar enamel system.

3.3.1 Prior to the application of the hot enamel the primed surface shall pass a test to determine the quality of the priming and its status.[8]
3.3.2 Surfaces failing to meet this test shall be reprimed.

3.4 COAL TAR ENAMEL SYSTEMS

3.4.1 Enamel hand applied to flat surfaces shall consist of a coat of primer over the properly prepared surface, hot enamel applied with daubers to a minimum thickness of 1/16 inch. At this stage the system must be free of holidays, etc., as tested for with a 10,000 volt holiday detector. A coat of coal tar emulsion is sprayed over the holiday free enamel coat.

3.4.2 *Yard System A*
a. Clean by system to be specified and prime
b. Two coats of enamel giving a minimum thickness of 3/32 inch
c. One wrap of 15 lb. asbestos pipeline felt
d. One wrap of heavy kraft paper

3.4.3 *Yard System B*
a. Clean by grit or sandblasting and prime
b. Coat with 2/32 inch enamel (minimum)
c. Wrap with fiber glass wrap (20 mil)
d. Coat with 2/32 inch of enamel (minimum)
e. Wrap with 15 lb. asbestos pipeline felt
f. Wrap with heavy kraft paper

3.4.4 *Yard System C*
a. Clean by system to be specified and prime
b. Apply two coats enamel, minimum of 1/16 inch in thickness
c. Apply one wrapping of glass fiber fabric
d. Apply third coat of enamel, minimum thickness 1/32 inch
e. Apply second wrapping of glass fiber fabric
f. Apply fourth coat of enamel, minimum thickness 1/32 inch

3.4.5 *Yard System D*
a. Clean by grit or sandblasting and prime
b. Apply one flood coat of enamel
c. Apply spiral wrap of fiber glass
d. Apply one flood coat of enamel
e. Apply spiral wrap of fiber glass
f. Apply one flood coat of enamel
g. Apply one spiral wrap of 15 lb. asbestos felt
h. Apply one spiral wrap of heavy kraft paper
i. Minimum thickness of this system, 3/16 inch

4.0 APPLICATION

4.1 *Application of coal tar primer.*

4.1.1 Immediately after the surface has been cleaned by the specified method, the metal surface shall be given a uniform coat of a coal tar primer recommended for use with the enamel to be used. This should be done the same day and preferably within a few hours of the surface preparation. It must be done before rust has formed on the surface.

4.1.2 Spraying equipment must be thoroughly cleaned before adding coal tar primer to the pressure pot. The spray equipment shall be equipped with adequate air filters or separators for the removal of oil and moisture from the compressed air. Mechanically agitated pressure tanks shall be used. Neoprene hoses should be used in handling coal tar primer.

4.1.3. The coal tar primer shall be thoroughly mixed or agitated in the drum before drawing each lot from the container.

4.1.4 The primer shall be applied at a rate of approximately 500 sq. ft./gal. (less coverage on rougher surfaces) in a uniformly thin film free from runs, drips, or missed spots.

4.1.5 All missed spots or areas covered with insufficient primer shall be touched up immediately with primer by hand brushing. Primer that has been applied too heavily, such as at the base of welds, shall be brushed out before the primer sets. Any runs or sags which have dried shall be scraped off and reprimed.

4.2 *Application of Coal Tar Enamel by Pipe Coating Yard*

4.2.1 The coating and wrapping of tubular steel in a pipe coating yard is so standardized, both from the standpoint of mechanization and personal technique that about all that is necessary is to specify the enamel to be used and the desired system. The finished coated and wrapped steel should be checked for holidays and occasionally the system should be checked for proper bonding to the steel.

4.2.2 The enamel shall be sufficiently fluid so that the fiber glass is pulled in and felt wraps are bonded to it, thus insuring proper bonding.

4.3 *Application of Coal Tar Enamel by Hand to Flat Surfaces*

4.3.1 No enamel shall be applied to a primer that has lost its life or fails to meet the tests in 4.3.2.

4.3.2 The primed surface shall pass one or both tests as indicated in 3.3.1.

4.3.3 The enamel shall be applied in such a manner that it will adhere tightly to the steel surface in a continuous unbroken film.

4.3.4 In hand brushing enamel with Tampico fiber daubers a special technique is necessary in order to obtain satisfactory application. At the start of the job, applicators should receive special instruction from the technical expert representing the manufacturer of the enamel.

4.3.5 Pouring and ragging will be permitted, but mopping or irregular smearing will not be permitted.

4.3.6 The surface shall be clean, dry and above 45 F during the application of the enamel. The enamel shall not be applied during rainy or foggy weather.

4.3.7 All enamel shall be firmly bonded to the steel surface.

4.3.8 Repairs to the coating shall be performed by an experienced touch up crew. All unbonded or loose coatings are to be removed by scraping. When the defective area exceeds 2 square inches the surfaces shall be cleaned to base metal by scraping and wire brushing. The bare metal shall be reprimed. After the primer has dried properly hot enamel shall be applied to a thickness necessary to withstand the 10,000 volt holiday testing. In the repairing of areas less than 2 sq. in., repriming will not be required. Instead, the area shall be repaired with enamel alone.

4.4 *Application of Coal Tar Emulsion over Hot Applied Enamel*

4.4.1 Manufacturer's recommendations in the handling of coal tar emulsion shall be strictly adhered to.

4.4.2 It is advisable to rinse spraying equipment with water prior to using a coal tar emulsion.

4.4.3 The emulsion is to be stirred preferably with a mechanical stirrer in the drum before drawing each lot from the containers.

4.4.4 Coal tar emulsions are not to be thinned.

4.4.5 The spray equipment used shall be equipped with adequate air filters or separators for the removal of oil and moisture from the compressed air.

4.4.6 The emulsion is to be applied at a rate of 50-60 sq. ft./gal.

4.4.7 Complete and even coverage is to be obtained.

4.4.8 After application the equipment should be thoroughly rinsed and cleaned with water.

5.0 INSPECTION

5.1 *Inspection, General*

5.1.1 The operator shall be represented by an inspector to insure conformance with the job specifications. All work done under these specifications shall be subject to inspection.

5.1.2 All parts of the work shall be accessible to the inspector.

5.1.3 The inspector shall have the right to inspect at all times any tools, materials, or equipment used, or to be used in the performance of the coating application.

5.1.4 The inspector shall have the right to condemn any and all equipment or work which does not conform to the specifications. Condemned areas will be clearly marked or outlined with chalk.

5.1.5 Any defective work or work not conforming to specifications shall be redone by the contractor by an experienced touch up crew at no additional cost to the operator.

5.1.6 All coal tar enamel applications, whether yard coated and wrapped or hand applied enamel, shall pass a 10,000 volt holiday test. Any areas failing to meet this test shall be repaired until the test is met.

5.1.7 All coal tar enamel applications are expected to be tightly bonded to the steel. Periodic tests will be made to check the bond.

5.1.8 If the inspector is unable to be on the job after reasonable notice has been given, then the contractor may begin the work without the inspector.

References

1. Koppers Company Bitumastic Pipe Line Handbook. Koppers Company, Inc., Tar Products Division, Koppers Building, Pittsburgh 19, Pennsylvania.
2. Pipeliner's Handbook. Protective Coatings Division, Pittsburgh Coke & Chemical Company, Grant Building, Pittsburgh, Pennsylvania.
3. Barrett Field Manual. Barrett Division, Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
4. Reilly Enamel Application Procedure. Reilly Tar & Chemical Corporation, 11 South Meridian Street, Indianapolis 4, Indiana.
5. SSPC-SP-5-52 "Blast Cleaning to White Metal." Steel Structures Painting Council, 4400 Forbes Avenue, Pittsburgh 13, Pennsylvania.
6. SSPC-SP-6-52 "Commercial Blast Cleaning." Steel Structures Painting Council.
7. SSPC-SP-3-52T "Power Tool Cleaning Specifications." Steel Structures Painting Council.
8. Tests specified in references 1, 2, 3 and 4.

Publication 57-9

Vinylidene Chloride Resins

A Report of NACE Technical Unit Committee T-6A

On Organic Coatings and Linings for Resistance to Chemical Corrosion*

*Prepared by Task Group T-6A-3 on Vinylidene Chloride Polymers***

Foreword

COMMITTEE T-6A was organized for the purpose of assembling and disseminating to the corrosion engineer, factual and quantitative data on the performance and limitations of the various organic materials that are successfully used in coatings and linings. While every attempt is made to be factual in the coverage of application and chemical resistance tables and physical properties, it nevertheless should be recognized that changes in compounding formulations of organic materials for coatings or linings enhance or detract from their inherent corrosion resistance characteristics. Under such circumstances, these reports and recommendation lists must be viewed as showing average properties only. The possibility of changes in chemical and physical characteristics as produced by various manufacturers or applicators of the material should be kept in mind.

Abstract

Vinylidene chloride resins can be formulated into coatings characterized by exceptional resistance to water, fuels and gases. Resistance to acids, salt solutions and mild oxidizing agents is excellent to good while alkali resistance is fair to poor. The two commercially available forms of vinylidene chloride resins are the copolymers with vinyl chloride and acrylonitrile.

Recommendations are made regarding the use of vinylidene chloride coatings in various media including several acids, alkalis, oils, oxidizing agents, salts, solvents, gases and water. These recommendations were compiled from experience reports by a number of users.

Physical properties of vinylidene chloride resins are given. Application of coatings is discussed in detail with attention given to coverage and shipping data, flammability and toxicity, surface preparation, priming and application methods. Properties of applied coatings and linings are considered with respect to temperature limitations, impact and abrasion resistance, hardness, aging, toxicity and odor, weight and electrical properties. **5.4.5**

Definition

Vinylidene chloride resins, as they apply to the protective coatings industry, may be defined as "the copolymers of vinylidene chloride with acrylonitrile or vinyl chloride, in which vinylidene chloride is the major component." While polyvinylidene chloride and copolymers of vinylidene chloride with a wide variety of reactive monomers are known, the acrylonitrile and vinyl chloride copolymers are the only vinylidene chloride resins used commercially in corrosion control at this time.

Use and Summary of Properties

Properties, uses and chemical composition of vinylidene chloride resins are quite similar to the vinyl resins. Applied from solvent systems they are used extensively for industrial corrosion resistant maintenance coatings. Factory lined pipe and pipe fittings and sheet lined tanks and process equipment are also in extensive use where a high degree of resistance to oils, solvents, and oxidizing conditions is required.

Vinylidene chloride resins, because of their very high chlorine content, produce non-flammable, dense films that have excellent barrier properties. They are basically resistant to most common inorganic acids, weak alkalis, hydrocarbon solvents and oils. They are adversely affected by strong alkalis and some organic solvents, especially the ketones and esters. They have a high degree of resistance to oxidizing agents when compared to other organic coatings, but are adversely effected by continued contact with strong oxidizing agents.

Forms Available

Vinylidene chloride resins are available and in corrosion-control use in the following general forms:

1. Four to ten mil coatings deposited from solutions.
2. Uncured calendered and molded elastomeric sheet applied linings (not covered in this report).
3. Factory lined pipe and pipe fittings which can be readily cut and assembled in the field (not covered in this report).

The solvent deposited coatings are applied normally in dry film thicknesses of four to ten mils by multiple applications. They are designed primarily for tank and vessel linings and maintenance coatings where protection from and resistance to corrosive chemicals, hydrocarbon solvents, inorganic acids etc. is required.

Effect of Compounding

The compounding requirements of vinylidene chloride copolymer coatings vary greatly depending on the use application. For tank and vessel lining

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** R. L. Brown and S. F. Roth, The Dow Chemical Co., Midland, Mich., chairmen.

TABLE 1—Vinylidene Chloride Resin Reference Chart

Thermoplastic (TP) or Thermosetting (TS)	TP
Water Absorption (percent after 2 weeks at 25 C, 1 mil film)	0.15
Moisture Vapor Transmission Rate (gm./24 hr./100 sq. in. @ 100 F 90-95% RH, 1 mil film	0.15
Maximum Safe Temperature for Continuous Exposure	150 F
Weathering	Slight yellowing
Odor	None
Flammability	Will not support combustion
Dielectric Strength, volts/mil at 60 cycles	1700

LEGEND:

R = Recommended; LR = Limited Recommendation (Test before using)
NR = Not Recommended.

Chemical Resistance Properties

Corrosive	Resistance
ACIDS	
Acetic, dilute	NR
Acetic, glacial	NR
Citric	R
Hydrochloric, dilute	R
Hydrochloric, conc.	R
Nitric, 10%	R
Nitric, 40%	LR
Nitric, conc.	NR
Phosphoric, 10%	R
Phosphoric, 60%	LR
Phosphoric, conc.	NR
Sulfuric, 50%	R
Sulfuric, 70%	LR
Sulfuric, conc.	NR
ALKALIES	
Ammonium Hydroxide, dilute (10% NH_3)	NR
Ammonium Hydroxide, conc. (28% NH_3)	NR
Calcium Hydroxide, (Slaked Lime Slurry)	R
Sodium Hydroxide, 20%	LR
Sodium Hydroxide, 70%	NR
Amines, all types	NR
GASES	
Chlorine	LR
Bromine	NR
Carbon Dioxide	R
Hydrogen Sulfide	R
Sulfur Dioxide	LR
OILS	
Animal	R
Vegetable	R
Mineral	R

Corrosive	Resistance
OXIDIZING AGENTS	
Hydrogen peroxide, 3%	R
Bleach	R
Perchloric Acid, 10%	R
Conc. oxidizing agents, all types	LR
SALTS	
Alum	R
Copper sulfate	R
Ferric salts	LR
Magnesium sulfate	R
Potassium permanganate	LR
Silver nitrate	R
Sodium bisulfite	R
Sodium carbonate	R
Sodium chloride	R
Sodium nitrate	R
Sodium sulfate	R
Sodium sulfite	R
SOLVENTS	
Alcohol, methyl	LR
Alcohol, all others	R
Glycols and glycerine	R
Hydrocarbons aliphatic	R
Hydrocarbons aromatic	LR
Hydrocarbons chlorinated	LR
Ethers	NR
Esters	NR
Ketones	NR
OTHERS	
Nitrobenzene	NR
Gasoline, leaded	R
Gasoline, aviation	R

applications where barrier and resistance properties are of prime importance, unmodified coatings are ordinarily used and give the best protection and performance. The U. S. Navy's Bureau of Ships Paint Formula No. 113/49 is an example of this type of coating in which the only modification is a small amount of orange and white pigment used as a visual aid in multiple coating. In other more conventional applications, vinylidene chloride resin coating formulations, like the vinyl systems, contain pigments, plasticizers and stabilizers of various types. These materials become integral parts of the protective film and have an effect on the final performance and barrier properties of the coating. Since formulations vary among various manufacturers and may even vary between batches from the same source, it is recommended that performance always be tested under actual service conditions. The data presented herein pertains to representative formulations in extensive use for corrosion control.

Resistances

The two commercially available forms, the vinyl chloride and acrylonitrile copolymers vary only slightly in resistance properties. The reference chart and corrosion list in Table 1 were compiled from data obtained from vinylidene chloride/acrylonitrile coating resins.

Water & Moisture

Vinylidene chloride copolymer coatings have extremely good water and moisture resistance. Water absorption of a typical vinylidene chloride coating resin is 0.15 percent after two weeks immersion at 25 C. Water vapor transmission rate of this resin is 0.15 gms./100 sq. in./24 hr./1 mil thickness at 100 F and 95 percent relative humidity. Salt water resistance is also excellent. These coatings are being used and can be recommended for marine and other applications where long severe water exposure is encountered.

Inorganic Acids

Vinylidene chloride resin coatings are resistant to all the common inorganic acids and generally these coatings can be recommended for applications requiring continuous acid immersion. The strongly oxidizing acids nitric, chromic and concentrated sulfuric tend to cause embrittlement of vinylidene chloride resin coatings. However, in many cases they are satisfactory under conditions less severe than continuous immersion, but service tests under actual exposure conditions are recommended before using.

Oxidizing Agents

Vinylidene chloride copolymer coatings have been successfully used to protect against many mild oxidizing agents such as bleaching solution and dilute hydrogen peroxide. Very strong oxidizing conditions adversely affect these coatings, however, and it is recommended that tests be run to verify suitability in service against these agents.

Organic Acids

Experience with resistance of the vinylidene chloride resins to organic acids has been very good generally. Sufficient variations have been reported, however, especially among the stronger acids such as acetic, trichloroacetic, chlorosulfonic etc. to suggest verification under service conditions before using.

Alkalis

Strong alkalis cause degradation of vinylidene chloride copolymer resins and immersion in caustic solutions stronger than 20 percent cannot be recommended. The less reactive alkalis such as calcium hydroxide are not harmful. Immersion in slaked lime slurries has been without effect. Resistance to amines and ammoniacal solutions is fair to poor and vinylidene chloride resins should be given a thorough testing before use against these agents.

Salt Solutions

Resistance of vinylidene chloride resins to salt solutions is excellent. The only exceptions reported

are the oxidizing salts such as the ferric and phosphoric salts and potassium permanganate. Some failures have been noted with these.

Solvents

Vinylidene chloride copolymers are dissolved or softened by ketones, esters and ethers. Resistance to aromatic and chlorinated hydrocarbons may be considered fair to good although service tests are recommended before using. Resistance to the commonly encountered aliphatic hydrocarbons such as gasoline, kerosene, mineral spirits etc. is very good. The U. S. Navy uses vinylidene chloride resins to line tanks used to store and transport aviation gasoline, jet fuel, Diesel oil and lubricating oil. Resistance of these resins to alcohols and glycols is excellent.

Oils

Animal, vegetable, and mineral oils do not have any effect on vinylidene chloride resin coatings.

Gases

Rate of passage of the common gases through vinylidene chloride copolymer barriers is extremely low. Oxygen transmission of a typical copolymer for example is 0.67 cc/100 sq. in./24 hours/mil at a pressure differential of one atmosphere at 25 C.

Properties of Applied Coatings and Linings

Temperature Limitations

Vinylidene chloride copolymer coatings are thermally stable at moderate temperatures and to brief exposures at elevated temperatures such as those encountered during high temperature drying. Applications requiring continuous exposure to temperatures exceeding 150 F (65.5 C) should be avoided as prolonged exposures at these temperatures may affect the barrier properties of the coatings. The flexibility of unplasticized vinylidene chloride copolymers below 0 F is poor. Where flexibility below this temperature is required plasticizers must be added.

Impact and Abrasion Resistances

Thoroughly dried unplasticized films of high vinylidene chloride copolymers are tough and slightly extensible. They are not subject to shattering under impact above 0 F. The abrasion resistance of clear or lightly pigmented formulations is in the range of 0.50 to 1.0 mil/1000 revolutions as measured on the Tabor Abrasor with CS-10 wheel under a 1000 gm. load.

Hardness

A typical vinylidene chloride copolymer used for industrial coatings has a Sward Rocker Hardness of 31. This property was measured on a 1.5 to 2 mil film at 23 C.

Aging

Properly pigmented and stabilized formulations have good aging and weathering properties. Yellowing occurs on weathering of unstabilized clear coatings.

Toxicity and Odor

The vinylidene chloride coating resins are odorless, tasteless and non-toxic. They are widely used in the packaging of food products as coatings on paper, Cellophane and polyethylene. Toxic gases are evolved on pyrolysis of vinylidene chloride resins, however, and when such operations as welding or torch-cutting of tanks coated with these resins is performed, proper ventilation precautions should be observed.

Weight of Applied Coatings or Linings

The vinylidene chloride copolymers used as solution resins vary in specific gravity from 1.60 to 1.75. Applied coatings will vary from these figures depending on the amount and specific gravities of pigments and plasticizers.

Electrical Properties

A 1.3 mil film of a typical vinylidene chloride/acrylonitrile copolymer has a dielectric strength of 1700 volts/mil at 60 cycles and a surface resistivity greater than 10^{13} ohms.

Application

Vinylidene chloride resins are available as solutions in volatile solvents, sheeting (Saran rubber) and factory lined pipe and fittings (Saran lined pipe). Saran rubber and Saran lined pipe are not covered in this report.

Coverage

Solutions of vinylidene chloride resins vary widely in specific gravity and coverage depending on the specific resin used, resin concentration, pigmentation etc. As one example, Bureau of Ships Paint Formula No. 113/49, a lightly pigmented, low solids solution coating, has a specific gravity of 0.84 to 0.94 and a weight per gallon of 7 to 7.8 lb. Coverage on this formulation varies widely depending on application techniques. The average calculated coverage is 148 square feet per gallon for a one mil coating. Coverage can range from as low as 50 square feet per gallon for sprayed intermediate and topcoats to 150 or more square feet for brushed primer coats.

Flammability and Toxicity

Vinylidene chloride copolymer solution coatings generally are dissolved in ketone and ketone-aromatic hydrocarbon mixtures, vapors of which are both toxic and flammable. Prolonged breathing of these vapors must be avoided and masks should always be worn by those applying these formulations in enclosed areas. In almost all cases vinylidene chloride resin solutions will have a flash point below 80 F and will require a red label. The Bureau of Ships Paint Formula specifies 84.3 to 88 percent methyl ethyl ketone and would have a flash point approaching that of the solvent (35 F). The safety precautions necessary to insure the safe application of flammable, volatile material should always be

used when handling these solutions. An excellent reference on this subject is the paper by C. G. Munger, entitled, "Vinyl Coatings Are Safe."[1]

Surface Preparation

Vinylidene chloride resin solutions, like the vinyls, have poor wetting and penetrating properties and it is necessary to use the best possible method of surface preparation to insure satisfactory adhesion and protection. Blast cleaning should be used wherever possible. A No. 2 commercial finish or better should be used in blasting.[2]

Priming

It may or may not be advisable to use primers with vinylidene chloride copolymer solution coatings, depending on the composition of the particular formulation being applied. The vinylidene chloride/acrylonitrile copolymers such as are used in Bureau of Ships Paint Formula No. 113/49 exhibit poor adhesion characteristic when used over conventional primer systems and the recommended application procedure is to apply these coatings directly to a freshly blasted surface. Primers are useful with the vinylidene chloride/vinyl chloride solution coatings, however and are furnished by the manufacturer of these products. Typical vinyl primer systems based on vinyl butyral or special vinyl copolymers are frequently used with these coatings.

Application Methods

Vinylidene chloride copolymer solution coatings are applied by brush, spray, dip, flow, or roller coating techniques. Some of the systems tend to web on spraying and the recommendations of the manufacturer on application techniques should be followed at all times in order to insure a successful installation.

References

1. Vinyl Coatings are Safe. C. G. Munger. *Safety Review,* **1950**, 7, 8, Aug. *National Safety News,* August., **1950,** incomplete Gasoline Resistant Tank Coatings. W. W. Cranmer. *Corrosion,* **8,** 195-204 (1952) June.

2. Report on Surface Preparation of Steels for Organic and Other Protective Coatings. NACE Pub. 53-1. A Report of TP-6G. *Corrosion* **9,** 173-185 (1953) May.

NACE TECHNICAL COMMITTEE REPORTS

Publication 57-10

Protective Coatings for Atmospheric Use: Their Surface Preparation and Application Requirements, Physical Characteristics and Resistances

A Preliminary Report by NACE Technical Unit Committee T-6B on Protective Coatings for Resistance to Atmospheric Corrosion*

Abstract

Detailed information is given on the application requirements, physical characteristics and resistances of 22 different types of binders. Materials discussed Include drying oil paints, ester gum-oil, straight phenolic oil varnish, modified phenolic oil varnish, straight alkyd varnish, modified alkyd varnish, epoxies, chlorinated rubber, vinyls, metallic silicate (zinc loaded), six coal tar coatings and five asphalt coatings. Information pertaining to the following points is given for each material: recommended surface preparation, number of coats, approximate dried film thickness of each coat, approximate air-drying time before recoating, usual method of application, application surface temperature, thinners, general flammability classifications, compatibility with other types, abrasion resistance, gloss retention, resistance to petroleum oil and grease, maximum temperature limitations, approximate storage life under normal conditions, and health hazards.

The information given pertains primarily to the use of coatings for the protection of steel as used in bridges, tanks, towers, fences and railroad cars exposed to rural, industrial and marine atmospheres. Data given are not applicable for strongly corrosive chemical or marine atmospheres. 5.4.5

Introduction

THE FUNCTION of Technical Unit Committee T-6B on Protective Coatings for Resistance to Atmospheric Corrosion is to study and summarize factual information on paints and other protective coatings that are practical for protection of metal exposed to the atmosphere. This report is concerned primarily with the protection of steel as used in bridges, tanks, towers, fences and railroad cars exposed to normal rural, industrial and marine atmospheres. It excludes, however, the strongly corrosive chemical or marine atmospheres because these are being reported on separately by other unit committees. Many of the principles described in this report do however apply to the maintenance of structures in these more aggressive atmospheres.

Scope

The type of material used for protection will vary with the service exposure and the life expectancy required, or other economic justifications. A normal rural atmosphere is comparatively mild because the only deteriorating influence is the weather. Strong sunshine may lead to rapid degradation of some materials. The rural environment may be dry or wet and damp. An industrial atmosphere generally is thought of as that found in urban regions near industrial plants or industrialized areas. One characteristic of an industrial atmosphere is a high concentration of sulfur dioxide. This factor increases corrosion rates and attack on the protective system.

Industrial atmospheres—such as found near coke plants—are not generally thought of as industrial but rather as chemical environments. Similarly, environments near some kinds of industrial or chemical plants may be classed as chemical because of the presence of strongly corrosive agents such as acid fumes, atomized solutions or alkali dust, mist, solvent vapors or any of a host of deteriorating substances.

A normal marine atmosphere is one similar to the humid rural atmosphere but it includes chloride salts in varying concentrations. An atmosphere of this kind may be found about the superstructure of a bridge remote from waves or splash action. Paint life in a marine atmosphere will vary from that equivalent to a humid rural atmosphere to one comparatively short under severe conditions.

Materials discussed in this report may be used for chemical atmospheres provided care is exercised to select those with resistance adequate to the environment. The severity of a chemical environment may vary from mild exposure in yard areas remote from the source of chemical contamination to extremely corrosive situations such as produced by immersion in strong chemicals. Materials adequate for occasional splash or spillage may be selected and used as paints when continuous immersion does not occur. More complete discussions of chemical exposures are available.[1,2,3,4,5]

Special services often require special paint formulation. Railroad cars, for example, are subjected to many environments and much abuse. It is difficult to obtain economical paint protection on hopper cars and gondolas. As a result many railroads paint these cars with low-cost short-lived paints such as the ester-gum paints.

Building frames to be encased in concrete or en-

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closed in masonry may not require painting but where necessary superficial painting is adequate.

The borderline cases between non-corrosive and corrosive service frequently require good appearance which helps justify the cost of painting.

Selection of Materials

Proper selection of coating materials is necessary for economical protection. Materials discussed in this report have extremely wide variations in resistance to water, oxygen, sunlight and chemicals. Their physical characteristics and application requirements are also widely varied. Probably the most important factor affecting the total cost of a paint system is surface preparation. Materials with poor wetting characteristics require expensive surface preparation procedure (see section on surface preparation in this report). In addition to the following discussion and chart, reports by Committee T-6A on vinyls, epoxies, neoprene, asphalt, chlorinated rubber, rubbers, vinylidene chloride, phenolics and furanes should be studied as they become available.

Drying Oil Paints

Linseed oil paints represent by far the largest class of drying oil based paints. Minor amounts of tung oil and other oil base paints are used. All drying oil protective coatings have somewhat similar characteristics. They are noted for resistance to ultraviolet light and weather, have adequate elasticity and are low in cost. They are used extensively for exterior exposures. Their principal disadvantage is their poor resistance to chemical environments including such mild ones as aliphatic solvents. They saponify in the presence of alkali or alkaline corrosion products and form soluble soaps which may be washed from the surface. Water resistance is poor unless they are very thoroughly oxidized. They are too soft to be satisfactory under abrasive conditions. Their high build per coat and low cost result in economical performance in milder exposures.

Drying oils are characterized particularly by their good wetting ability. They are used over millscale and residues of rust which remain when surface preparation other than blast cleaning or pickling is used.

Rust inhibitive primers must be used for effective protection; topcoats suitably pigmented for resistance to the environment are required to protect the primer.

Typical paints are:

Primer: Federal Specification TT-P-86a, "Paint; Red-Lead-Base, Ready Mixed," Type I, "Red Lead-Linseed Oil Paint."

Finish: Federal Specification TT-P-61b, "Paint; Ready-Mixed, Black."

Ester Gum—Oil

Ester gum is a resin made from rosin. Chemical combination with polyhydric alcohols increases its resistance but it still has comparatively poor resistance to water, sunlight and weather. As a result, paints made with ester gum have shorter service life than the better (and more expensive) materials such as drying oils, alkyds and phenolics. The principal application for ester gum-oil material is for low cost painting. The material is satisfactory for some types of railroad rolling equipment, for building frames to be encased in concrete or enclosed in masonry where water does not reach the frame, or for temporary coatings where long life is not required.

The ester gum usually is cooked into a varnish with some type of drying oil. For better wetting of the surface, the ester gum varnish is often mixed with a drying oil.

Typical paints are:

Primer: SSPC-Paint 13-55T, Red or Brown One-Coat Shop Paint.

Finish: Two pounds aluminum paste per gallon of Fed. Spec. TT-V-81b, varnish; mixing for aluminum paint, Type I, Class B.

Straight Phenolic—Oil Varnish

Oil soluble phenolic resins may be used to make varnishes that have moderate resistance to inorganic acids and mild alkalis. They are more resistant to these corrosives than straight drying oils or alkyds. They are particularly resistant to water. Because these varnishes have a considerable range of composition extensive variations in properties are possible.

Wide variations in the kinds of phenolic resin are possible also. The shorter the oil length of the varnish, the greater the resistance to water and mild chemical environments but the greater the brittleness of the dry film. As the oil length is increased in the varnish the dry film takes on characteristics of drying oils with their inferior resistance to chemicals and water. Although tung and linseed oil are used principally with phenolic resins, dehydrated castor oil frequently is employed to improve water resistance.

These resins, called "100 percent phenolic" type include typical widely used resin known as the para-phenylphenol formaldehyde type. This type resin has properties different from thermosetting types commonly used for organic linings because they are thermoplastic in nature and non-heat reactive.

Because the phenolic varnish has better chemical resistance than drying oils, ester gum, or alkyds, considerable use is made of phenolic paints in severe exposures. Such exposures include those involving high humidity and condensation, water immersion, mild chemical contamination and environments not severe enough to warrant paints such as vinyls or chlorinated rubber.

Typical paints are:

Primers: Federal Specification TT-P-86a, "Paint; Red-Lead-Base, Ready Mixed," Type IV, "Red Lead Mixed Pigment Phenolic Varnish Paint."

Federal Specification TT-P-57, "Paint, Zinc Yellow Iron Oxide-Base, Ready-Mixed." Type III, "Zinc-Yellow-Iron Oxide-Phenolic Varnish Paint."

Finish: SSPC-Paint 103-55T, "Black Phenolic Paint."

Modified Phenolic—Oil Varnish

To upgrade poor material such as rosins, tall oil and ester gum, phenolic resins are modified with rosin derivatives to produce inexpensive resins for oil varnishes. As a result of the modification of the phenolic resin by the chemically reactive rosin acids, the durability and chemical resistance of the 100 percent phenolic resin described is sacrificed while resistance of the rosin material is improved. Materials of this kind are used as low cost, primarily decorative coatings where the finish coat may be renewed frequently.

No specification paints are available as examples.

Straight Alkyd Varnish

Alkyd resins are extensively used for paints and perform well if not immersed in water or exposed to strong chemicals. Alkyds usually are made by reaction of drying oils, or drying oil fatty acids, with phthalic anhydride and glycerol—or other polyfunctional acids or alcohols. As a result, they have many of the properties of the drying oils. As the amount of drying oil is increased, the alkyd resin takes on more and more of the properties of the oil. If the phthalic anhydride content is increased instead, the resins become harder and more resistant, but their wetting ability is decreased. Because of variations in drying oils, organic acids and polyhydric alcohols which may be used, there are large numbers of alkyd formulations. Alkyds may be air drying or baking types.

Alkyd varnishes are not comparable to the conventional varnish because the oil constituents are included in the basic materials which react to form the alkyd resin. The resin exists in the liquid form and no "cooking" with oil is required. Linseed oil is often mixed with alkyd resin varnish to improve its wetting properties.

Primers: Federal Specification TT-P-86a, "Paint; Red-Lead-Base, Ready-Mixed," Type III, "Red-Lead-Alkyd Varnish Paint."

Federal Specification TT-P-57, "Paint, Zinc Yellow-Iron Oxide-Base, Ready-Mixed," Type II, "Zinc Yellow-Iron Oxide-Alkyd Varnish Paint."

Finish: SSPC-Paint 101-55T, "Ready-to-Mix Aluminum Alkyd Paint."

Modified Alkyd Varnish

Rosin often is used to modify alkyd varnish to reduce cost. Modification of the alkyd by the rosin reduces color retention, water resistance and durability of films but it improves gloss, hardness and drying speed. This type material is considered in row F of Table 1. Another type alkyd modification is that resulting from addition of styrene. Some styrene modified alkyds show considerable improvement over the alkyd itself, but complete evaluations have not been made.

No specifications are available for modified alkyd resin paints.

Epoxies

Epoxy resins are formed by reaction of epichlorhydrin with bisphenol-A which is the condensation product of phenol and acetone. The resulting resin has good chemical resistance and stability. Paints formulated from epoxy resins generally have good color retention and impact resistance. Epoxy resin coatings may be baked to cure or may be air dried at ambient temperatures by including suitable curing agents such as amines. The amine cured coating is inferior to baked coating in chemical and water resistance.

Air drying epoxy coatings may be formulated by reacting epoxy resins with oil fatty acids to form an ester. The resulting epoxy ester will air dry like a drying oil paint but the resulting film is decidedly inferior to the straight epoxy resin in chemical, water and abrasion resistance. Because of the addition of the oil fatty acids the ester will wet surfaces containing residues of rust and millscale better than unmodified epoxy resin.

Epoxy resin paints include rust inhibitive pigments in the priming coat and conventional finish coat pigments in the topcoats. The amine cured epoxy should not be pigmented with zinc-containing pigments. Straight epoxy coatings are outstanding in resistance to alkalis and may be applied as high-solids coatings producing high film thickness per coat.

Specifications are not available for epoxy paints.

Chlorinated Rubber (Natural)

Chlorinated rubber is obtained by treating natural rubber with chlorine until the solid residue contains about 67 percent chlorine by weight. The material is a hard resin and must be plasticized to make elastic paint films. Stabilizers are added in exterior chlorinated rubber paints to prevent deterioration by ultraviolet light. Often linseed oil or alkyd resin is added to the priming coat for better adhesion to steel. The oil or alkyd serves the dual purpose of improving adhesion and acting as a plasticizer. Chlorinated rubber and other chlorinated resins which may be used as plasticizers produce films resistant to fire and mildew.

Chlorinated rubber paints have a long record of successful use in protecting interiors subjected to corrosive chemicals or dampness. Newly developed materials have given excellent service outdoors.

Chlorinated rubber vehicles generally are classified into three types. Type A, which includes chlorinated resins and plasticizers in addition to chlorinated rubber, has maximum chemical resistance and is used in direct contact with acids or alkalis or for severe fume conditions, etc.

Type B contains about the same amount of chlorinated rubber as Type A (50 to 60 percent of vehicle solids) but has oil or alkyd resins in place of the chlorinated resin and in addition to the chlorinated plasticizer. It is used primarily on alkaline surfaces, such as concrete and masonry.

TABLE 1—Protective Coatings Resistant to Atmospheric Corrosion for Steel Bridges, Tanks, Towers, Fences and Railroad Cars[1]

1	2	3	4	5	6	7	8
Binder	**Recommended Surface Preparation. (Refer to Steel Structures Painting Council Specifications)**	**Number of Coats**	**Approximate Dried Film Thickness of Each Coat (mils)**	**Approximate Air-Drying Time Before Recoating (Hours)**	**Usual Method of Application**	**Application Surface Temperature (Temperature at Least 5 F Above Dew Point)**	**Thinners; Solvents**
Linseed or A–other drying oil	Solvent removal of oils, etc., wire brush to remove mill scale, rust, paint and other loose products; preferably blast clean to commercial or brush-off finish	2 primers; 1 or 2 finish	Primer 2 Finish 2	72 (untreated oils)	Any practical method-brush, spray dip or roller	40 to 120 F	Mineral spirits, naphtha or turpentine
Ester gum-B–oil	Remove oil, blast clean to a commercial or brush-off finish	2 primer 1 or 2 finish	Primer 1½ Finish 1½	4–16	Any practical method-brush, spray, dip or roller	40 to 120 F	Mineral spirits, naphtha or turpentine
Straight C–phenolic oil varnish	Remove oil, blast clean to a commercial or brush-off finish	2 primer 1 or 2 finish	Primer 1½ Finish 1½	4–16	Any practical method-brush, spray, dip or roller	40 to 120 F	Solvent naphtha high aromatic, mineral spirits, turpentine
Modified D–phenolic oil varnish	Remove oil, blast clean to a commercial or brush-off finish	2 primer 1 or 2 finish	Primer 1½ Finish 1½	4–16	Any practical method-brush, spray, dip or roller	40 to 120 F	Solvent naphtha, high aromatic, mineral spirits, turpentine
Straight E–alkyd varnish	Remove oil, blast clean to a commercial or brush-off finish	2 primer 1 or 2 finish	Primer 1½ Finish 1½	4–16	Any practical method-brush, spray, dip or roller	40 to 120 F	Solvent naphtha, high aromatic, mineral spirits, turpentine
Modified F–alkyd varnish resin	Remove oil, blast clean to a commercial or brush-off finish	2 primer 1 or 2 finish	Primer 1½ Finish 1½	4–16	Any practical method-brush, spray, dip or roller	40 to 120 F	Mineral spirits or turpentine
Epoxy fatty G–acid ester	Remove oil, blast clean to a commercial or brush-off finish	1 primer 1 or 2 finish	Primer 1½ Finish 1½	2–16	Any practical method-brush, spray, dip or roller	40 to 120 F	Mineral spirits and aromatic
Epoxy, H–amine-cured	Remove oil, blast clean to a commercial or brush-off finish; commercial blast cleaning or better	1 primer 2 finish	Primer 2 Finish 2	4–8	Any practical method-brush, spray, dip or roller. Spray preferable	60 to 120 F	Ketone-alcohol aromatic blend
Chlorinated I–rubber	Remove oil, blast clean to a commercial or brush-off finish; commercial blast cleaning or better	1 primer 3 finish	Primer 1 to 1½ Finish 1 to 1½	1 to 4	Any practical method-brush, spray, dip or roller. Spray preferable	40 to 100 F	Aromatic and aliphatic blends
J–Vinyl	Remove oil, blast clean to a commercial or brush-off finish; pickle, metal conditioner or special primer if necessary; commercial blast cleaning or better	1 or 2 primer 2 finish	Primer ¾ to 1 Finish 1 to 1½	½ to 1 2 to 4	Any practical method-brush, spray, dip or roller. Spray preferable	40 to 100 F, at lower temperature under some conditions	Ketone and aromatics, alcohols for conditioner
Metallic K–silicate (Zinc loaded)	Sandblast to white metal	1 coat (baked or chemically cured)	2½	2 before baking or chemical curing	Brush or spray	40 to 120 F	Water (should not be thinned)
Coal tar L–fluid, light duty	Same as for linseed oil or ester gum oil	(no primer) 2	2	2 to 4	Brush, spray	40 to 160 F	Coal tar solvent
Coal tar M–medium viscosity, medium duty	Same as for linseed oil or ester gum oil; Vinyl metal conditioner (wash primer) optional	2 or 3	8	½ to 1 primer 24 to 48	Brush, spray	40 to 160 F	Alcohols for conditioner coal tar solvent (thinning not recommended)
Coal tar N–solvent type, high consistency, heavy duty	Remove oil, blast clean to a commercial or brush-off finish; vinyl metal conditioner (wash primer) optional	2 or 3	18 to 22	½ to 1 primer 24 to 48	Brush, pump-spray	40 to 160 F	Alcohols for conditioner coal tar solvent (thinning not recommended)
Coal tar O–emulsion type, high consistency, heavy duty	Remove oil, blast clean to a commercial or brush-off finish; vinyl metal conditioner (wash primer) optional	Cutback primer (unless wash primer is used) 2 or 3	Primer 2 11 to 13	2 to 4 12 to 24	Brush, pump-spray	40 to 160 F	Alcohols for conditioner water (thinning not recommended)
Coal tar P–solvent type, emulsion type, combination, both high consistency, heavy duty	Remove oil, blast clean to a commercial or brush-off finish; vinyl metal conditioner (wash primer) optional	1 or 2 solvent type 1 emulsion finish	18 to 22 11 to 13	½ to 1 primer 24 to 48	Brush, pump-spray	40 to 160 F	Alcohols for conditioner Coal tar solvent water (thinning not recommended)
Coal tar, Q–hot applied enamels	Remove oil, blast clean to a commercial or brush-off finish	1 solvent type primer 1 enamel 1 emulsion	3 60 to 125 11 to 13	1 to 24 None	Brush, spray Machine, brush, pump-spray, brush	40 to 160 F	Coal tar solvent None, water (thinning not recommended)
Asphalt, R–solvent type, fast-curing, non-fibered	Remove oil, blast clean to a commercial or brush-off finish	2	2½ to 3½	4	Brush, spray	40 to 160 F	Mineral spirits
Asphalt S–solvent type, fast-curing, fibered	Remove oil, blast clean to a commercial or brush-off finish	1 or 2	60 to 125 total thickness	4	Brush, pump spray trowel	40 to 160 F	Mineral spirits
Asphalt, T–emulsion type, non-fibered	Remove oil, blast clean to a commercial or brush-off finish	1 oil base primer 2 finish	1½ to 2 3 to 15	4	Brush, pump spray	40 to 160 F	Mineral spirits for primer water (thinning not recommended)

[1] This chart represents a guide only and final decisions should be made with the assistance of the paint manufacturer.

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TABLE 1 (Cont'd)—Protective Coatings Resistant to Atmospheric Corrosion for Steel Bridges, Tanks, Towers, Fences and Railroad Cars[1]

9	10	11	12	13	14	15	16
General Flammability Classifications	Compatibility with Other Types	Abrasion Resistance	Gloss Retention	Resistance to Petroleum Oil and Grease	Maximum Temperature Limitations	Approximate Storage Life Under Normal Conditions	Precautions to Prevent Health Hazard
Normal precautions	If used as primer under estergum, phenolic, or alkyd coating film must be throughly dry and hard; incompatible with vinyl, coal tar, chlorinated rubber, etc.	Fair	Fair	Fair	Good to 250 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space.
Normal precautions	As primer, may be coated with other types, except for high solvency coatings such as epoxy, chlorinated rubber, coal tar and vinyl coatings	Good	Good	Fair	Good to 250 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space.
Normal precautions	As primer, may be coated with other types, except vinyl and coal tar coatings	Very good	Good	Good	Good to 300 F	Up to 18 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Normal precautions	As primer, may be coated with other types, except for high solvency coatings, such as epoxy, chlorinated rubber, coal tar and vinyl coatings	Good	Good	Good	Good to 250 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Normal precautions	As primer may be coated with other types, except for high solvency coatings, such as epoxy, chlorinated rubber, coal tar and vinyl coatings	Good	Good	Good	Good to 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Normal precautions	As primer, may be coated with other types, except for high solvency coatings, such as epoxy and chlorinated rubber coatings	Good	Good	Good	Good to 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Normal precautions	Data being collected. Patch test advisable	Very Good	Fair	Good	Good to 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Extreme precautions	Data being collected. Patch test advisable	Very good	Fair	Very good	Good to 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Extreme precautions	As primer, may be coated with some other types. Patch test advisable	Good	Good	Good	Good to 160 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Extreme precautions	Generally compatible only with vinyl. Patch test advisable	Very good	Good	Very good	Good to 150 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed space; check for toxicity.
Does not ignite	Cannot be applied over other types; can be coated over using special primers	Excellent	Not glossy	Excellent	500 F	Up to 24 months	Avoid prolonged breathing of fumes; masks should be used when spraying; check for toxicity.
Normal precautions	Patch test advisable; bleeds through conventional paints	Fair	Fair	Good	200 F	Unlimited	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection and skin cream recommended.
Normal precautions	Generally incompatible; patch test advisable over old paints	Fair	Poor	Good	400 F	Unlimited	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection and skin cream recommended.
Normal precautions	Generally incompatible	Fair	Poor	Good	160 F	24 months	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection and skin cream recommended.
Does not ignite	Patch test advisable over other types; aluminum varnish sealer recommended, if color top coat applied	Fair	No gloss	Good	250 F	12 months (avoid freezing)	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection and skin cream recommended.
Normal precautions Does not ignite	Aluminum varnish sealer recommended, if color top coat applied	Fair	No gloss	Good	160 F	24 months 12 months (avoid freezing)	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection and skin cream recommended.
Normal precautions Does not ignite	Aluminum varnish sealer recommended, if color top coat applied	Excellent	No gloss	Good	160 F	Unlimited 12 months (avoid freezing)	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection and skin cream recommended.
Normal precautions	Cannot be used under most oil paints; may be covered with emulsion paints, or with shellac; may be used over cured oil paints or varnishes. Patch test advisable	Fair	Fair	Poor	Good to about 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed spaces; skin cream recommended.
Normal precautions	Cannot be used under most oil paints; may be covered with emulsion paints, or with shellac; may be used over cured oil paints or varnishes. Patch test advisable.	Fair	No gloss	Poor	Good to about 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed spaces; skin cream recommeded.
Normal precautions Does not ignite	Cannot be used under most oil paints; may be covered with emulsion paints, or with shellac; may be used over cured oil paints or varnishes. Patch test advisable.	Fair	No gloss	Poor	Good to about 300 F	Up to 24 months (avoid freezing)	Avoid breathing fumes and spray; provide ventilation in closed spaces; skin cream recommended.

[1] This chart represents a guide only and final decisions should be made with the assistance of the paint manufacturer.

(Continued on Page 91)

TABLE 1 (Cont'd)—Protective Coatings Resistant to Atmospheric Corrosion for Steel Bridges, Tanks, Towers, Fences and Railroad Cars[1]

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Binder	Recommended Surface Preparation. (Refer to Steel Structures Painting Council Specifications)	Number of Coats	Approximate Dried Film Thickness of Each Coat (mils)	Approximate Air-Drying Time Before Recoating (Hours)	Usual Method of Application	Application Surface Temperature (Temperature at Least 5 F Above Dew Point)	Thinners; Solvents
Asphalt, U-dispersion type, fibered	Remove oil, blast clean to a commercial or brush-off finish	1 oil base primer or vinyl metal conditioner (wash primer) optional 1 finish	1½ to 2 (0.3) 60 to 125	4 to 24 ½ to 1	Brush, spray Pump-spray, flow	40 to 160 F	Mineral spirits for oil base primer; alcohols for conditioner (thinning not recommended) solvent
Asphalt, V-hot applied enamels	Remove oil, blast clean to a commercial or brush-off finish	1 primer 1 enamel	1½ to 2 40 to 90	2 to 4 None	Brush, spray Dip, brush	40 F minimum	Mineral spirits primer finish, none

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Type C is used extensively for structural steel work and contains 20 to 40 percent chlorinated rubber and 60 to 80 percent long oil alkyd or drying oils in the vehicle solids. It has less chemical resistance than Type A or B but maximum adhesion to structural steel and is quite suitable as a priming paint.

Specifications for chlorinated rubber paints are not available.

Vinyls

Vinyl resins used in metal protective paints are a series made from copolymerized vinyl compounds. The main constituents of vinyl resins are vinyl chloride and vinyl acetate. This copolymer is a relatively inert insoluble resin of water white color that has outstanding durability and resistance. It is soluble only in special types or combinations of solvents. Vinyl resins have poor adhesion to metal.

To improve adhesion constituents such as maleic acid are added. The resulting resins have good adhesion to steel, to other vinyls, or to other paints. They differ from ordinary paints because they do not oxidize but dry solely by solvent evaporation in the same manner as lacquers. As a result of the low boiling point solvents in which they usually are dissolved, they are extremely fast drying. Their inertness and fast drying properties make them useful and they are used in solutions with low solids content.

Their poor wetting ability limits their use to clean steel. Adhesion is improved by application over vinyl butyral wash primer.[6] High solids vinyl paints and vinyl mastics have been developed recently. Hot application vinyls are employed to improve film thickness per coat. Vinyl alkyds are sometimes added to improve brushing and gloss retention with sacrifice of some of the normal chemical resistance.

Special primers have become available recently which improve adhesion of vinyl coatings, in many cases even where old coatings remain on the surface. These make it possible to use vinyl coatings over previously applied coatings which remain tightly adhered to the surface.

Typical straight vinyl system specifications are:

Primer: U. S. Military Specification MIL-P-15929A, "Primer, Paint, Vinyl-Red Lead Type, Formula No. 119"; or,

U. S. Military Specification MIL-P-15930A, "Primer, Paint, Vinyl-Zinc Chromate Type, Formula No. 120." These must be used over a wash primer pretreatment such as MIL-C-15328A, "Coating, Pretreatment Formula No. 117 for Metals."

Finish: SSPC-Paint 8-55T, "Vinyl Aluminum Paint"; or SSPC-Paint 9-55T, "White or Gray Vinyl Paint."

Metallized Silicate (Zinc Loaded)

A number of coatings based on mixtures of zinc dust and sodium silicate are available today which provide atmospheric corrosion resistance of a very high degree. Evidence indicates that effective metal protection can be obtained over a five to ten-year period when they are applied properly. These materials are applied with standard painting equipment but must be chemically cured or baked. Cold curing results when a curing solution is added to facilitate the reaction between the zinc and silicate and which solidifies the coating at ordinary temperatures. These materials may, therefore, be applied to existing equipment provided surfaces are blasted. The end product is a mat finish with excellent adhesion and excellent abrasion resistance.

While these materials do not have many of the deficiencies associated with organic films, they are brittle and have little resistance to alkalis or acids.

No specifications are available for zinc silicate coatings.

Coal Tar Coatings

Coal tar and coal tar products are available in large quantity in this country as a by-product of the coking industry. They make particularly good coatings for resistance to water and fumes because of their extremely low water absorption and low water vapor permeability. They are fairly inert and may be applied in very thick coatings. Exposure to sun-

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Normal precautions Does not ignite	Cannot be used under most oil paints; may be covered with emulsion paints, or with shellac; may be used over cured oil paints or varnishes. Patch test advisable.	Fair to good	No gloss	Poor	Good to about 300 F	Up to 24 months	Avoid breathing fumes and spray; provide ventilation in closed spaces; skin cream recommended.
Normal precautions	Patch test advisable, sealer coat recommended	Fair	Poor	Poor	160 F	Unlimited	Avoid breathing fumes and spray; provide ventilation in closed spaces; eye protection recommended; skin cream recommended.

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light and weather generally leads to alligatoring and to eventual failure by cracking. This may be overcome by application of a filled pitch-base emulsion topcoat.

For extremely severe service, adequate protection requires the use of coal tar pitch base products applied in thick coatings and in many cases protected by the emulsified topcoat or external wrapping. Coal tar pitches are used extensively in the form of cutbacks or solutions (either filled or unfilled), as hot applied coatings, or as aqueous emulsions. Wash primers may be used underneath cold applied coal tar coatings. Because thick coats dry slowly, high solvency aromatic solvents are used in coal tar cutbacks. This may cause lifting of conventional paints when cutbacks are heavily applied over them. Patch tests generally are advisable to determine compatibility.

Coal Tar Fluid, Light Duty. Coal tar cutbacks without fillers are used as protective coatings in mild environments. A protective system consists of two or more coats of the light duty coal tar cutbacks.

Primer: U. S. Bureau of Reclamation Specification CTP-3, "Coal Tar Paint."

Finish: U. S. Bureau of Reclamation Specification CTP-3, "Coal Tar Paint."

Coal Tar Medium Viscosity, Medium Duty. This type of coal tar cutback contains a filler such as silica or slate flour and because viscosity is considerably higher the coating can be applied in thick films. This film thickness reduces permeability of the system. Lifting of oil-type primers and in some cases alligatoring upon exposure to sunlight may be aggravated by the thicker coatings. Because of high viscosity, special equipment is necessary for spraying. The resulting thick coatings afford protection in severe environments where light duty coating might be questionable.

No specifications are available for this material.

Coal Tar Solvent Type, High Consistency, Heavy Duty. Extremely thick coal tar coatings which are fluid cutbacks of a buttery nature are used for extremely corrosive conditions. Special spray equipment utilizing compound pumps is required. Because of the alligatoring which occurs upon exposure to sunlight, this fluid cutback often is utilized in a protective system consisting of one or two coats of the cutback with one coat of coal tar emulsion as a topcoat. The coal tar emulsion prevents alligatoring and has extremely good resistance to sunlight and weather.

Primer or Finish: U. S. Military Specification MIL-C-18480, "Coating Compound, Bituminous, Solvent, Coal Tar Base"; or
U. S. Bureau of Reclamation Specification CA50, "Coal Tar Paint."

Alternative Topcoat: U. S. Military Specification MIL-C-15203, "Coating, Bituminous Emulsion."

Coal Tar Emulsions. Emulsions differ from conventional coatings employing volatile solvents in that the tar is dispersed in water by means of emulsifying agents. Emulsions may be severely damaged by freezing either in storage or after application before they dry unless they are formulated to withstand low temperatures. Emulsions also must be protected from rain or water during their drying period. Because of the high consistency of the coal tar emulsion, it must be applied by special spray equipment of the type used for thixotropic cutbacks. If the emulsion is used alone, the primer recommended by the manufacturer should be applied.

Typical coal tar paints are:

Alternative Primer: Metal conditioner (wash primer), or proprietary coal tar primer, or paint primer of proved compatibility.

Primer and Finish: U. S. Military Specification MIL-C-15203, "Coating, Bituminous Emulsion."

Coal Tar, Hot Applied Enamels. Filled coal tar pitches are used under very corrosive atmospheric conditions or on surfaces immersed in water. The enamel is melted and applied hot over a surface previously primed with a thin cutback coal tar primer. Coal tar enamels may be plasticized or unplasticized and correct selection depends upon the temperature range to be encountered. The primer used should be that recommended for the enamel selected. It is imperative that good bond be obtained between the hot

enamel and the cutback primer. If there is an extended time interval between priming and enameling, it may be necessary to apply a fresh coat of primer. The correct technique in application of coal tar primer and enamel is important and for that reason it is advisable to have thoroughly qualified applicators. Plasticized type enamels usually are used for atmospheric exposure.

Typical coatings are:

Primer and Enamel: American Water Works Association Specification C203-51, "Coal Tar Enamel Protective Coatings for Steel Water Pipe of sizes 30 inches and over; or

U. S. Navy Bureau of Yards and Docks Specifications 34Yb "Bituminous Coating of Steel Surfaces."

Topcoat: U. S. Military Specification MIL-C-15203, "Coating, Bituminous Emulsion."

Asphalt Coatings

Asphalt is used in cutbacks cooked with oil to form a varnish, an emulsified or a solid pitch, or a filled enamel which is melted prior to application and applied hot. Asphalt has good resistance to weather and to inorganic acidic environments, but is believed to have greater water absorption and permeability than coal tar. Service from asphalt coatings depends a great deal upon the type used. Natural asphalts, such as gilsonite and wurtzilite, sometimes are used in coatings, but generally are compounded with petroleum base asphalts. Petroleum base asphalts consist of residues from distillation of crude petroleum which have been refined by steam distilling, oxidizing or other means to improve their quality.

Asphalt, Solvent Type, Fast-Curing, Non-Fibered. Thin coatings result when this low consistency, liquid material is used. For this reason systems are built up in multiple coats. Because of the low solvency of petroleum solvents, asphalt cutbacks may be applied over conventional types of paint with little danger of lifting dried films. They are less susceptible than coal tar cutbacks to alligatoring, but more susceptible to damage from contact with oil or grease.

A typical paint is:

Primer and Finish Coat: Federal Specification SS-A-701 "Asphalt-Frimer; (for Roofing and Waterproofing)."

Asphalt, Solvent Type, Fast Type Curing, Fibered. Asphalt cutbacks often are filled, just as are coal tar cutbacks, to make thicker, high consistency coatings. Because of the film thickness, more protection is afforded. Usually a blend of asphalts is combined with inorganic fillers, such as asbestos fibers, mica, slate flour, silica, etc. This material, because of its high consistency also requires special spray equipment. Conventional rust inhibitive primers are recommended for use under asphalt cutbacks in very corrosive service.

Primer and Finish Coat: SSPC-Paint 12-55T, "Cold Applied Asphalt Mastic;" or

Primer: Any of the rust inhibitive primers previously listed.

Finish: SSPC-Paint 12-55T, "Cold Applied Asphalt Mastic."

Asphalt Emulsion Type, Non-Fibered. Asphalt emulsions with better weather durability than cutbacks are available either as clay or chemical type emulsions. If permitted to become thoroughly dry before exposure, they give very satisfactory protection against water. Asphalt emulsions should not be permitted to freeze in storage or after application until thoroughly dry. Generally rust inhibitive primers should be used.

Typical paints are:

Primer: Oil base or oleoresinous primer previously listed.

Finish Coat: U. S. Military Specification MIL-R-3472, "Roof-Coatings; Asphalt-Base Emulsion."

Asphalt Dispersion Type, Fibered. This material is similar to asphalt emulsions except that vehicles other than water are used to produce dispersions. It is said to have better stability and freezing resistance than water emulsions, to cure more rapidly and to adhere better. No specifications are available for this material.

Asphalt, Hot Applied Enamel. Asphalt cutback is first applied as a primer and allowed to dry. Hot asphalt enamel is then applied. It is recommended that both primer and enamel come from the same supplier as a complete system to avoid incompatibility.

Primer and Enamel: U. S. Military Specification MIL-P-1227A, "Primer and Enamel, Asphalt."

Use, Application and Summary of Properties

Service obtained from paints and coatings depends upon selection of the proper material, correct surface preparation, and good application, particularly adequate film thickness. Generally care should be taken to prevent intercoat contamination. Adequate drying periods between coats to eliminate solvent entrapment should be a practice.

Surface Preparation

The most important factor governing the life of a protective coating is surface preparation. This subject is discussed thoroughly—along with techniques and equipment—in an NACE Technical Report.[6] Specifications for Surface Preparation have also been issued by the Steel Structures Painting Council.

Recommendations for surface preparation in Table 1 should be followed for optimum service. However, in milder environments, rigorous surface preparation is not mandatory and some of the less effective methods such as wire brushing or scraping may be satisfactory—particularly if good wetting paints are

used. When costly methods of surface preparation such as blast cleaning and pickling are used, then it is imperative to protect the investment in the surface preparation by applying high quality, highly resistant paints in adequate film thickness. Pretreatment of the surface is beneficial if a pretreatment with the coating is selected and if the surface is prepared in accordance with requirements for the pretreatment. In some cases (for example, when some vinyls are used) pretreatment is mandatory. Caution should be exercised in using pretreatments which are said to eliminate the necessity for good surface preparation. A similar measure of caution should be used in applying paints said not to require good surface preparation.

Application

Improper application will ruin a costly paint job even though the best surface preparation and materials are used. Care should be exercised to assure that surface is dry, temperature and humidity of the air are correct, surface is not too cold and not too hot, coating will not freeze and coating will not be subjected to rain before curing. Special effort should be expended to ensure that critical areas, such as edges, crevices, welds, rivets, bolts are adequately protected. A stripe coat over these places often is advantageous in building up extra film thickness. Discontinuities must be avoided. Correct film thickness is essential and can be checked by instruments available to measure wet or dry film thickness. A detailed specification covering application requirements has been issued by the Steel Structures Painting Council and is available as SSPC-PA-1-55T, "Shop, Field and Maintenance Painting."

Application data for paints and coatings used for atmospheric exposures are included in Table 1.

References

1. K. Tator. Protective Coatings—15th Materials of Construction Report. Chem. Eng., **59,** No. 12, 143-190 (1952) Dec.
2. Application Techniques, Physical Charactertistics and Chemical Resistance of Polyvinyl Chlor-Acetates (A Report by Unit Committee T-6 A on Organic Coatings. *Corrosion,* **10,** 349-354, (1954) Oct.
3. Report on Rigid Polyvinyl Chloride. (A Report of NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. *Corrosion,* **12,** 193t-186t, (1956) April.
4. Report on Epoxy Resins. (A Report of NACE Technical Unit T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. *Corrosion,* **12,** 187t-190t, (1956) April.
5. Report on Application Techniques, Physical Properties and Chemical Resistance to Chlorinated Rubber Coatings. (A Report of NACE Technical Unit Committee I-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. *Corrosion,* **12,** 191t-195t, (1956) April.
6. Report on Surface Preparation of Steels for Organic and Other Protective Coatings. (Second Interim Report of TP-6G —Surface Preparation for Organic Coatings). *Corrosion,* **9,** 173-185, (1953) May.

Partial protection is also very desirable in many cases involving poorly coated lines and can be justified by reductions in sinking fund deposit factors due to increased pipe life, in addition to usual savings in operations.

Electrical engineers should anticipate that cathodic protection will effect savings in other corrosion areas. Power plant equipment, cables, substations, docks, ships and other situations involving metals in contact with soils and solutions are fertile fields for the application of cathodic protection and modern techniques of corrosion control

5.2.1-56 CORROSION CONTROL OF STEEL EQUIPMENT. T. R. B. Watson. **Can. Chem. Processing, 37,** No. 10, 46, 48, 50, 52, 54 (1953) Sept.

Describes causes of corrosion and discusses control by means of cathodic protection.

5.2.1-57 CATHODIC PROTECTION LICKS CORROSION. L. C. Werkin. **Petroleum Refiner, 31,** No. 9, 122-124 (1952) Oct.

Cathodic protection, a positive, controllable and inexpensive method of preventing corrosion. There is real money in reducing these losses caused by corrosion-maintenance, replacement costs, over-design of equipment, and product losses. Refinery management and technical personnel must be keenly aware of the creeping inroads of corrosion, and alert to any feasible solution to the problem. Table showing cost estimates and savings resulting from its use on a large open-box-type refinery condenser and a large diameter Dorr clarifier. 9 refs.

...THODIC PROTECTION OF STEEL. F. ...Nurse, H. C. K. Ison and T. W. Farrer. ...ry, No. 40, 972-974 (1952) Oct. 4.

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5.2.2 PREVENTIVE PROTECTION, AN...

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5.2.2-1 CATHODIC PRO... ANODES. Brochure, June, 1953 ...tute, 60 East 42nd Street, New

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Technical Practices Committee Officials Named

E. C. Greco To Take Over Chairmanship At Conference

E. C. Greco, United Gas Corporation, Shreveport, Louisiana has accepted appointment as chairman of NACE's Technical Practices Committee beginning the last day of the 1957 NACE Conference and ending on the last day of the 1959 NACE Conference. Greco succeeds C. P. Larrabee, United States Steel Corporation, Monroeville, Pennsylvania who has been chairman since the end of the 1955 NACE Conference.

Greco

Mr. Greco graduated from Northwestern Louisiana State College with a BS in chemistry in 1934. During World War II he was Chief Explosives Chemist for U. S. Army Ordnance and Special Chemist, Development, E. I. DuPont de Nemours & Co., Inc., Explosives Division. He is presently Senior Research Chemist, Research Department, United Gas Corporation in Shreveport.

He has been a member of NACE since 1946. Since that time he has served as secretary-treasurer of South Central region, vice-chairman and chairman of Group Committee T-1 on Corrosion in Oil and Gas Well Equipment, vice-chairman of Unit Committee T-1K on Inhibitors for Oil and Gas Wells and vice-chairman of the Technical Practices Committee. He was co-chairman of Symposia on Oil and Gas Production Industry at the 1953 NACE South Central Region Meeting and 1954 Annual Conference and chairman of similar symposia at the 1954 South Central Region Meeting and 1955 Annual Conference.

In addition to NACE activities Mr. Greco is a councillor of the American Chemical Society, president of the Louisiana Academy of Sciences and a member of the American Association for the Advancement of Science. He was chairman of the Natural Gasoline Association of America Plant Corrosion Committee in 1955. Technical papers by Mr. Greco have been published in CORROSION, *Chemical Engineering, Industrial and Engineering Chemistry* and elsewhere.

13th Conference News

News about the meetings of technical committees scheduled during the NACE 13th Annual Conference and Exhibition at St. Louis March 11-15 were published in February CORROSION as follows: Tentative Committee and Technical Program, Page 79.

Charleston Committee Becomes T-7 Unit

The Charleston (West Virginia) Coordinating Committee on Corrosion recently became a part of the NACE T-7 Corrosion Coordinating Committee organization. The committee is now designated T-7A-1 Charleston Coordinating Committee on Corrosion and operates under Technical Unit Committee T-7A Northeast Region Corrosion Coordinating Committee.

Officers of the committee for 1957 are Fred W. Lloyd, United Fuel Gas Company, chairman; K. R. Gosness, Godfrey L. Cabot, Inc., vice-chairman and H. W. Hetzer, West Virginia Water Service Company, secretary, all of Charleston, W. Va.

The committee was first organized in June, 1955 and now represents fifteen affiliates. The present area of operation extends west from Charleston to Nitro, West Va. and east to Malden and includes both sides of the Kanawha River.

R. E. Kuster Is Named Canadian T-7 Official

Ralph E. Kuster, Union Gas Company of Canada Ltd., Chatham, Ontario has accepted the vice chairmanship of the Unit Committee T-7F Canadian Region Corrosion Coordinating Committee. Mr. Kuster, B.A.Sc., graduated in Electrical Engineering Electronics option from the University of Toronto in 1949. After graduation, he was employed by the Bell Telephone Company in the Toll and Transmission Department where he specialized on stray current electrolysis of lead cables.

Kuster

Mr. Kuster is a director-elect on the NACE Board of Directors representing corporate membership. In addition to being vice chairman of T-7F he is a member of Unit Committee T-2H on Asphalt Type Coatings for Pipe Lines. He is secretary-treasurer of the NACE Canadian Region and a member of the American Gas Association Corrosion Committee.

Mr. Kuster served five years in the RCAF during World War II, three years as an Equipment Instructor at a Wireless School and was discharged as a commissioned pilot.

In Canada, Mr. Kuster has been an active officer of the Southern Ontario Committee on Electrolysis. Although re-organization is being planned, the Southern Ontario Committee on Electrolysis presently is made up of a gen-

(Continued on Page 96)

T. J. Maitland of American Telephone Is Vice-Chairman

T. J. Maitland, American Telephone and Telegraph Company, New York, N. Y. will become vice chairman of the Technical Practices Committee on the last day of the 1957 Conference. He was appointed to succeed E. C. Greco who will become chairman.

Maitland

Mr. Maitland has been engaged in corrosion mitigation work for over thirty years. He is a graduate of Worcester Polytechnic Institute in electrical engineering. His entire career with the exception of a few years spent as an instructor in electrical engineering at the University of New Hampshire, has been devoted to the control of corrosion and to cable construction and maintenance methods of long distance telephone cables. He is now Electrolysis and Protection Engineer, Long Lines Department of the American Telephone and Telegraph Company.

He has been responsible for the preparation of instructions covering corrosion testing methods and the construction of cathodic protection systems on cables installed or maintained by the A. T. & T. Co.

He has been a member of NACE since 1944, is the author of several technical papers presented at national conferences, published in CORROSION and presented at regional and section meetings. He was chairman of the Power and Communications Symposium at the 1956 Conference and currently is chairman of Unit Committee T-2B on Anodes for Impressed Currents and Task Group T-4B-1 on Lead and Other Metallic Sheaths.

As chairman of T-2B he has successfully completed a four year testing project in addition to a joint project with the National Electrical Manufacturers Association besides initiating several new committee projects. As chairman of T-4B-1 he has contributed much toward making Unit Committee T-4B one of the NACE's most active technical committees.

In addition to T-2B and T-4B-1, Mr. Maitland is a member of seven other NACE Committees.

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Battle and Koger Are Named to Offices On T-1 Committee

Battle

Koger

Jack L. Battle, Humble Oil & Refining Company, Houston, Texas will become chairman of Group Committee T-1 on Corrosion in Oil and Gas Well Equipment on the last day of the 1957 Conference in St. Louis. He was appointed to succeed W. F. Oxford, Jr., Sun Oil Company, Beaumont, Texas, chairman of T-1 for the past two years.

W. C. Koger, Cities Service Oil Company, Bartlesville, Oklahoma has been elected to succeed Mr. Battle as vice-chairman of T-1. He also will take office on the last day of the 1957 Conference.

Mr. Battle has been with Humble Oil & Refining Company since 1933. He was educated at Southern Methodist University and the University of Houston. He presently is Supervising Chemical Engineer in the Production Department of Humble. In 1952 he was instrumental in organizing Unit Committee T-1H and served as the committee's chairman through 1955 when he became vice chairman of T-1. He served as co-chairman of Oil and Gas Production Symposia at the 1956 NACE Conference and the 1956 South Central Region Meeting. He is co-chairman of the Oil and Gas Production Symposium at the 1957 Conference in St. Louis.

He has been a member of NACE since 1944, is a registered professional engineer, a member of the American Petroleum Institute, Mining and Metallurgical Engineers and the American Chemical Society. Several of his technical papers have been published in CORROSION and other technical publications.

Mr. Koger graduated from the University of Arkansas in 1944 with a BS in chemical engineering. He joined Cities Service Oil Company immediately after graduation and was assigned to refinery research. In 1946 he transferred to Cities Service Oil Company's Oil Production Division as Corrosion Engineer in the West Kansas Division. He presently is Head of the Corrosion and Oil Treating Section, Oil Production Division. Mr. Koger has been a member of NACE since 1951. He was instrumental in organizing the West Kansas Section of NACE, served as chairman of the West Kansas Area T-1H task group and is now chairman of Unit Committee T-1H on Oil String Casing Corrosion. Technical papers by Mr. Koger have appeared in CORROSION and other technical publications.

R. E. Kuster Is—

(Continued from Page 95)

eral committee, a technical committee and five technical sub-committees. The general committee is the governing body of the organization. The technical committee with its five sub-committees handles all corrosion cases presented to the organization. The technical committee recommends tests necessary, analyzes data obtained from tets and reports to the general committee. Currently the territory covered by the whole of Southern Ontario has been divided into five sections centering on Sarnia, London, Brantford, Hamilton and Toronto. A technical sub-committee is organized for each center. Over one hundred member companies have named representatives and alternates for both the general committee and technical committee.

Any member company of the committee preparing to alleviate corrosion problems notifies the proper sub-committee. Full details of the installation and drawings are forwarded for study. All owners of underground plant that may be affected in the same area are notified and co-operative tests are arranged to determine possible interference effects. In all investigations, it is understood normally that the disturbing party should restore affected structures to their original state.

In addition to acting as a clearing house for the solution of corrosion problems the committee is preparing a master map showing the location of all important cross-country underground plants in Southern Ontario, with all cathodic protection installations noted. The committee as a whole has been co-operating with the Canadian Region of NACE in developing standard procedures for corrosion control.

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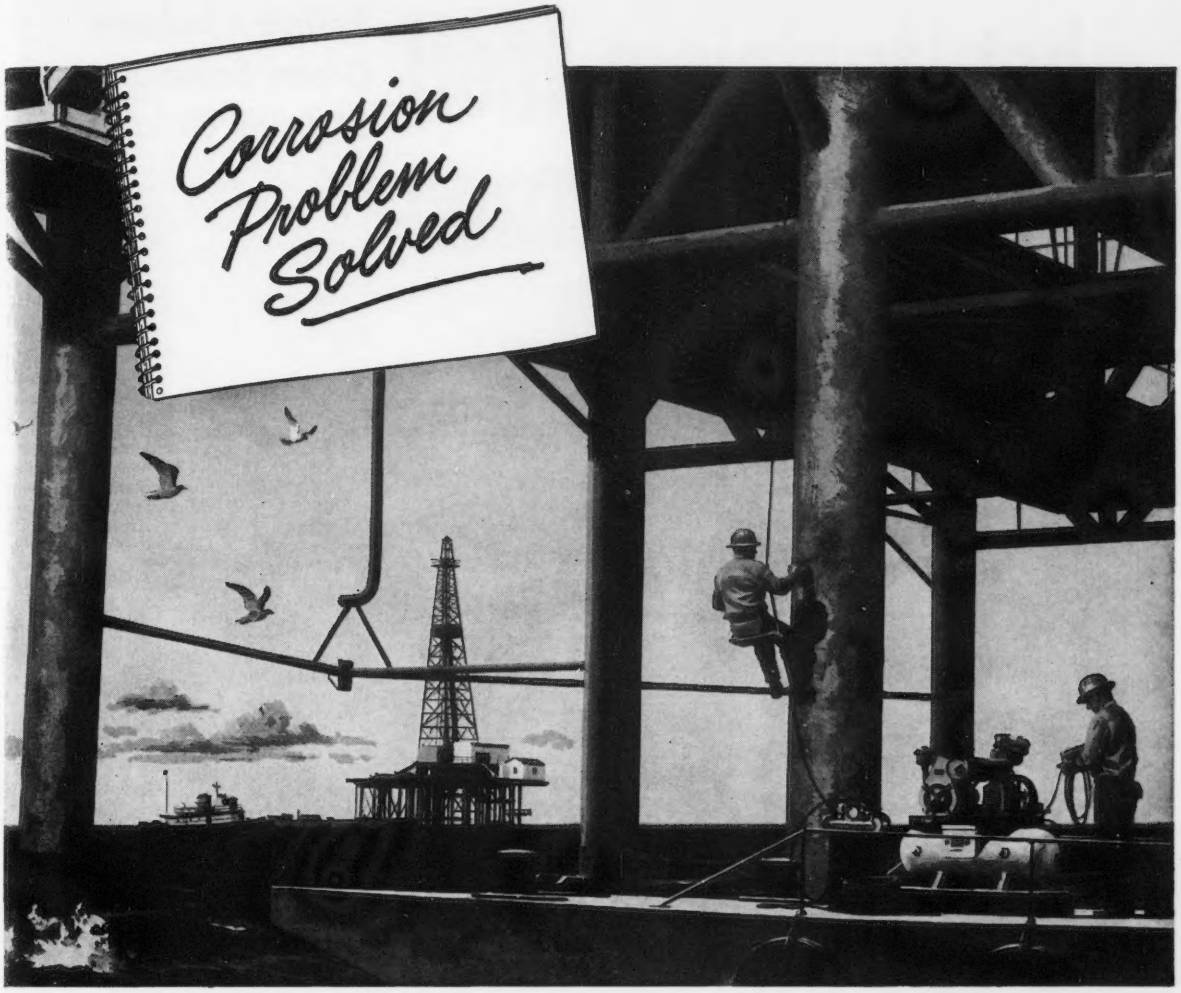

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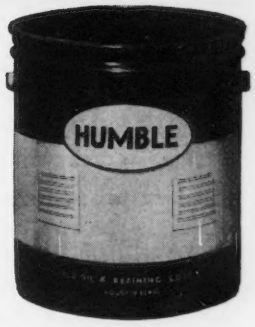

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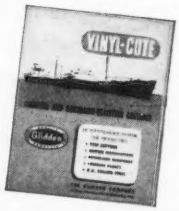

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Refinery Industry Group Schedules St. Louis Organization

A new NACE Technical Group Committee on Refinery Industry Corrosion Problems has been approved tentatively. The managing committee of the Technical Practices Committee will recommend approval of the new group at its meeting in St. Louis. Formation of a new group committee also is subject to approval by the NACE Board of Directors.

The tentative scope for the new group is: "This committee is concerned with the broad subject of corrosion of equipment used in the refining of crude oil and the manufacture of gasoline, lubricants and other related products. Its purpose is to develop a better understanding of corrosion associated with refining. It will endeavor to gather and compile data on the environments causing corrosion of refinery equipment, the extent and seriousness of corrosion problems and information on the various methods being used to control corrosion. Where warranted, unit committees will be formed to study problems brought to the attention of the group committee. An important function of the committee will be to provide a means for those interested in refinery corrosion to discuss and exchange information on the subject."

When finally approved the new group committee will be designated T-8. An organization meeting will be held during the 13th Annual NACE Conference in St. Louis.

The new group committee is an outgrowth of Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry. As a result of information furnished the task group since its formation in 1955 high temperature corrosion by hydrogen sulfide is now better understood and information is available as to several ways of combating this type of corrosion. Interest in the problem is, therefore, expected to decrease. However as additional operating experience develops, it is desirable that such information continue to be reported to a specific group.

New problems related to catalytic reforming and other refinery operations are developing that are of interest to those active in T-5B-2 as illustrated by discussions at the meeting of the task group in San Antonio, Texas last October.

Fourteen Coatings Committee Task Groups Organized

Fourteen new task groups have been organized under Technical Unit Committee T-6B on Protective Coatings for Resistance to Atmospheric Corrosion. Howard C. Dick, Products Research Service, Inc., New Orleans recently announced the formation of the new task groups and explained they were assigned to enlarge on information concerning specific coatings treated gen-

(Continued on Page 100)

R. I. Zimmerer to Be Process Industries Group Chairman

R. I. Zimmerer, Petro-Tex Chemical Corp., Houston, Texas has been appointed chairman of Group Committee T-5 on Corrosion in the Chemical Process Industries. He will succeed W. G. Ashbaugh, Carbide & Carbon Chemicals Co., Texas City, Texas, whose term expires on the last day of the 1957 Conference.

Zimmerer

Mr. Zimmerer is a native of Chicago, Ill. He was educated at the University of Cincinnati where he was graduated with a degree in chemical engineering in 1942. After four years in the armed services he joined Westvaco Chlor-Alkali Division of Food Machinery and Chemical Corporation in South Charleston, West Virginia. He worked with Westvaco as maintenance engineer until 1955 after which he joined Petro-Tex Chemical Corp. in Houston.

In addition to NACE Mr. Zimmerer is a member of the American Institute of Chemical Engineers and the Houston Coating Society. He was a charter member and organizer of the Kanawha Valley Coatings Society and the Kanawha Valley NACE Section. He is a past chairman of Task Group T-5A-4 on Chlorine and presently is chairman of Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry.

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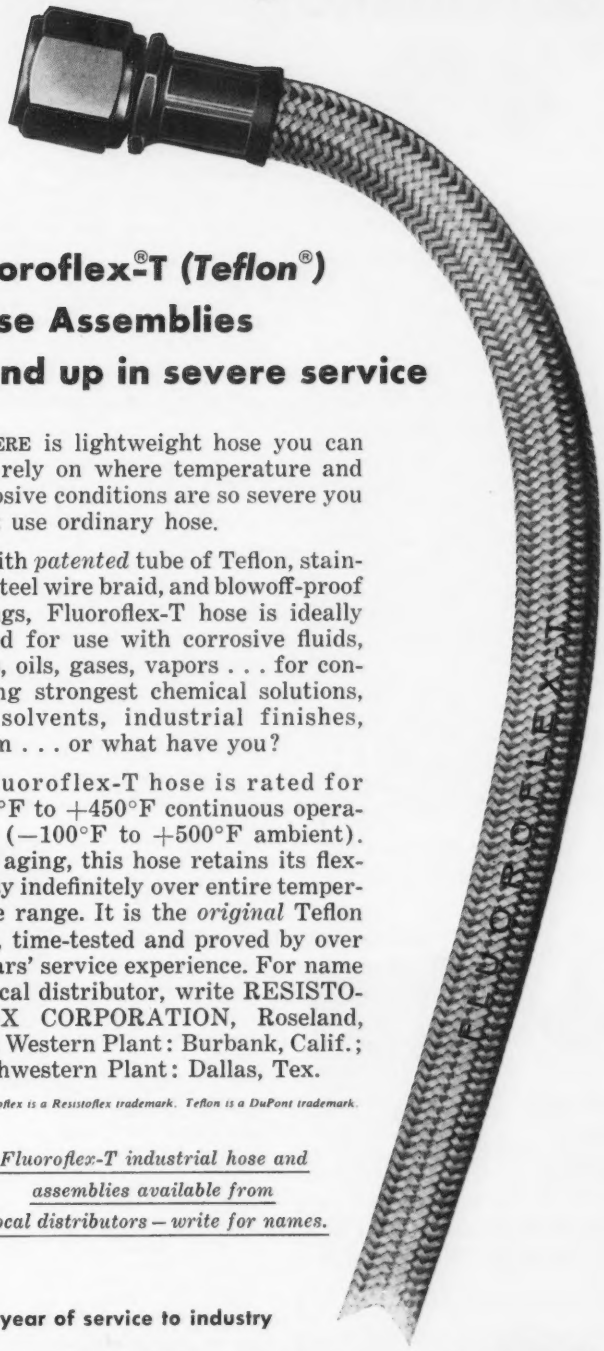

Fluoroflex-T (*Teflon*®) Hose Assemblies stand up in severe service

HERE is lightweight hose you can rely on where temperature and corrosive conditions are so severe you can't use ordinary hose.

With *patented* tube of Teflon, stainless steel wire braid, and blowoff-proof fittings, Fluoroflex-T hose is ideally suited for use with corrosive fluids, fuels, oils, gases, vapors . . . for conveying strongest chemical solutions, hot solvents, industrial finishes, steam . . . or what have you?

Fluoroflex-T hose is rated for −65°F to +450°F continuous operation (−100°F to +500°F ambient). Non aging, this hose retains its flexibility indefinitely over entire temperature range. It is the *original* Teflon hose, time-tested and proved by over 4 years' service experience. For name of local distributor, write RESISTOFLEX CORPORATION, Roseland, N. J. Western Plant: Burbank, Calif.; Southwestern Plant: Dallas, Tex.

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Fluoroflex-T industrial hose and assemblies available from local distributors—write for names.

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Roebuck Heads General Corrosion Problems Group

A. H. Roebuck, Continental Oil Company, Ponca City, Oklahoma has been appointed chairman of Group Committee T-3 on General Corrosion Problems. He succeeds Dr. F. W. Fink, Battelle Memorial Institute, Columbus, Ohio whose term expires on the last day of the 1957 Conference.

Roebuck

Dr. Roebuck received a master's degree from the University of Arizona and a PhD from the University of Texas. Before joining the research staff of Continental Oil Co., he was doing corrosion research work with the Reactor Engineering Division of Argonne National Laboratories where he studied the corrosion of stainless steel, zirconium and other metals at high temperatures.

He has been a member of NACE since 1954 and currently is chairman of Unit Committee T-1K on Inhibitors for Oil and Gas Wells and of Unit Committee T-3B on Corrosion Products. He has been vice chairman of T-3 since May, 1955.

He was chairman of the High Purity Water Symposium and co-chairman of the General Corrosion Problems Roundtable at the 1956 NACE Conference and is chairman of the General Corrosion Problems Roundtable to be held at the 1957 Conference. Technical papers by Dr. Roebuck have been published in CORROSION and elsewhere.

Clayton Is Chairman Of Task Group T-4B-3 On Tests and Surveys

H. M. Clayton, Standardization Engineer for the Memphis Light, Gas and Water Division has been appointed vice chairman of Task Group T-4B-3 on Tests and Surveys.

Clayton

Mr. Clayton was born in Waco, Texas, studied electrical engineering at Texas A & M College and served as a second lieutenant in the infantry during the first World War.

He was employed as a meter tester and repairman with the Texas Power and Light Company in Waco and the Little Rock Railway Electric Company in Little Rock, Arkansas for three years. He served as chief engineer and superintendent of the Electric Department for the Arkansas Central Power Company for three years and has been with the Memphis Power and Light Company for fourteen years.

Since 1939 he has served in the capacity as Standardization Engineer for the Memphis Light, Gas & Water Division. He organized and has directed the Corrosion Prevention Department of the division since 1950, supervising corrosion prevention on the electric, gas and water systems of the company. In addition to NACE Mr. Clayton is a member of AIEE and the National Association of Professional Engineers. He is a registered engineer of the State of Tennessee.

Fourteen Coatings—

(Continued from Page 98)

erally in the T-6B report published in the March, 1957 issue of CORROSION.

New task groups and their chairmen are:

T-6B-1 on Linseed and Other Drying Oils, Dr. Joseph Bigos, United States Steel Corporation, Monroeville, Pa., chairman.

Task Group T-6B-2 on Ester Gum Oil, R. L. Liston, Cook Paint and Varnish Co., Houston, Tex., chairman.

Task Group T-6B-3 on Straight Phenolic Oil Varnish, J. W. Nee, Briner Paint Mfg. Co., Corpus Christi, Tex., chairman.

Task Group T-6B-4 on Modified Phenolic Oil Varnish, J. W. Nee, chairman.

Task Group T-6B-5 on Straight Alkyd Varnish, G. G. Sward, National Paint, Varnish and Lacquer Association, Washington, D. C., chairman.

Task Group T-6B-6 on Modified Alkyd Varnish, G. G. Sward, chairman.

Task Group T-6B-7 on Epoxy Esters, F. McDougal, Shell Oil Company, New Orleans, La., chairman.

Task Group T-6B-8 on Epoxy (Amine Cured), E. Gould, Continental Oil Co., Harvey, La., chairman.

Task Group T-6B-9 on Chlorinated Rubber, O. Grosz, The California Co., Harvey, La., chairman.

Task Group T-6B-10 on Vinyls, R. M. Robinson, Continental Oil Co., New Orleans, La., chairman.

Task Group T-6B-11 on Metallic Silicates, L. L. Miner, Amercoat Corporation, Houston, Tex., chairman.

Task Group T-6B-12 on Coal Tar, M. Mitchell, Reilly Tar & Chemical Corp., Indianapolis, Ind., chairman.

Task Group T-6B-13 on Asphalt, C. C. Allen, Anderson-Prichard Oil Corp., Oklahoma City, Okla., chairman.

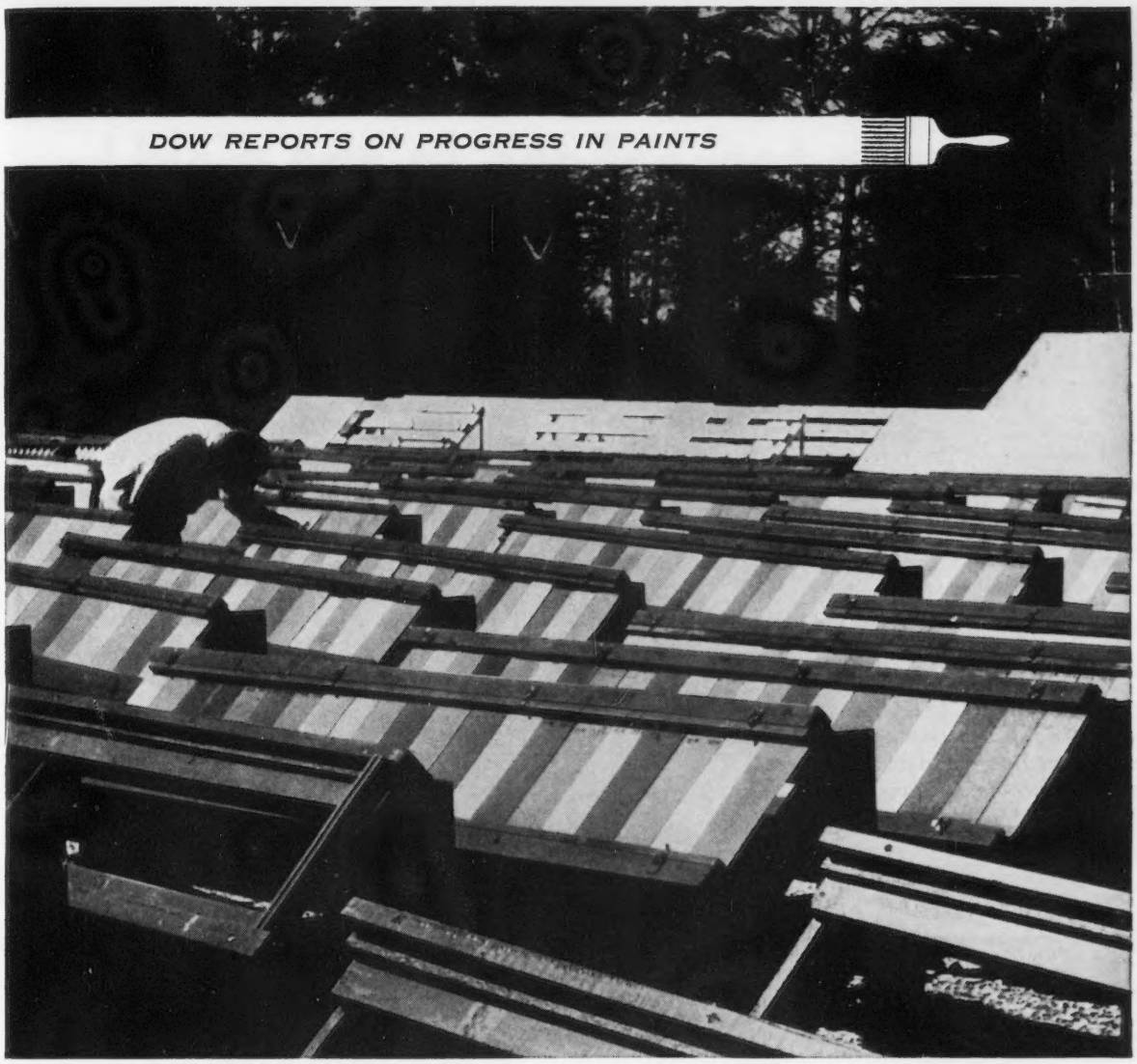
Task Group T-6B-14 on New Developments, Joe Rench, Napko Corp., Houston, Tex., chairman.

Maitland and Clayton Head Cable Sheath Unit

T. J. Maitland, American Telephone & Telegraph Co., New York City has been elected chairman of Technical Unit Committee on Corrosion of Cable Sheaths. He will preside at meetings of the unit at St. Louis.

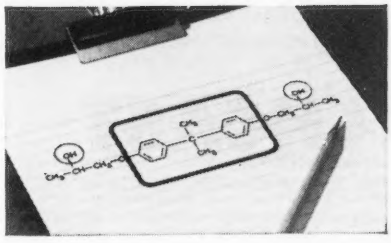
H. M. Clayton, Memphis Light, Gas and Water Division, Memphis, Tenn. has been elected vice-chairman of the unit. Both have long been active in the committee's work.

A paper describing a new corrosion testing device is scheduled to be presented at the committee's St. Louis session.



A paint testing area of The Dow Chemical Company

Chemical structure of Dow Resin 565 proves key to improvements in alkyds



It's small on paper—the center part of this formula. But it provides big improvements in alkyds. That's why Dow offers 565 as an ideal building block for the finest alkyd vehicles.

You'll like the way Dow Resin 565 adds superior chemical resistance, gloss and exterior durability. By building these properties into the alkyd with this intermediate, you may eliminate later additions to paint formulations.

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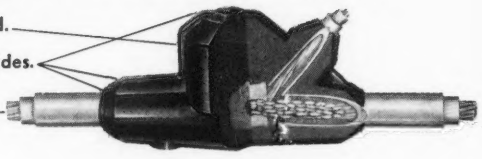
New "SCOTCHCAST" Splicing Kit gives maximum protection against moisture and electrial breakdown . . . solves splicing problems in rectifier ground bed installation

ALL MATERIAL for this revolutionary non-technical method of making wye or tap splice is included in new "SCOTCHCAST" Kit No. 90B1.

This cut-away view shows Factory-Tight "SCOTCHCAST" splice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Syracuse May 20-22 Meeting Program Outlined

PAST CHAIRMEN'S CERTIFICATES framed in stainless steel by U. S. Steel Corp. were awarded to seven past chairmen of Pittsburgh Section at its February meeting. W. F. Fair, Jr., Koppers Co., Inc., NACE president made the awards and talked on the association and its progress. Shown above are V. V. Kendall, National Tube Div., U. S. Steel Corp.; Dr. Fair; J. M. Bialosky, Koppers Co.; Russell H. Coe; N. P. Peifer and F. E. Costanzo, Manufacturers Light & Heat Co. Not present at the meeting to receive certificates were W. W. Binger, Alcoa Research Laboratories and W. G. Renshaw, Allegheny Ludlum Steel Corp. Forty-seven persons attended the dinner meeting.

Arthur B. Smith Is Elected Jacksonville Chairman

A business luncheon of Jacksonville, Florida Section was held at the Spanish Restaurant in Jacksonville January 28 to induct new officers and make plans for activities during 1957. New officers are as follows: Arthur B. Smith, Amercoat Corporation, chairman; Charles Carlisle, Industrial Marine Service Company, Inc., vice-chairman and John Hancock, Electric & Water Utilities, City of Jacksonville, secretary-treasurer.

The need for more active members in the Jacksonville Section was discussed and Charles Carlisle was named chairman of a membership commitee with Ray Tiffin as co-chairman. It was decided one way to increase the membership is to hold informative programs rather than the discussion type, held by the section in the past. One day meetings are contemplated.

H. T. Rudolf was named program chairman. Mr. Rudolf has planned a one day meeting tentatively for April 26, at which time papers will be presented on corrosion problems in utilities, transportation, pulp and paper and phosphate chemical industries; on corrosion control with chemical inhibitors, protective coatings and cathodic protection. Each paper will be folowed by a discussion period.

Next meeting after April will be in September.

100 Attend Kanawha Mid-Winter Meeting

Approximately 100 members and guests attended the mid-winter dinner meeting of Kanawha Valley Section NACE January 17 at the Henry Clay Hotel in Ashland, Kentucky. John Halbig, senior research engineer, Armco Research Laboratories, Middletown, Ohio spoke on Corrosion Resistant Steels for Industry. A question and answer period followed Mr. Halbig's talk.

During the afternoon preceding the meeting, NACE members and guests made a guided tour of Armco Steel Corporation's Ashland plant.

Next meeting of Kanawha Valley Section will be held March 28 in the dining room of the Kanawha County Airport, Charleston, West Virginia. A round table discussion on cathodic protection and its applications will be held by members of the Kanawha Valley Coordinating Committee on Corrosion at this meeting.

Northeast Region Sets Plant Tours And Demonstrations

Eleven technical papers, a round table session, demonstrations and two plant tours are scheduled during Northeast Region's May 20-22 meeting at Syracuse. Central New York Section and Syracuse University are cooperating with the region in presenting the program. Andrew Kellogg, Niagara Mohawk Power Corp., Syracuse, chairman of the meeting said the theme of the meeting is "Corrosion Control by Choice of Materials."

Social features include an informal shore dinner, and a ladies' program.

The program follows:

Monday, May 20

Registration, 9 am.
Formal opening, 10 am.
Corrosion principles, chemical inhibitors, pipe line corrosion, corrosion by high purity water, high temperature corrosion.

Tuesday, May 21

Corrosion in chemical industry, lead sheathed cables, communication lines, cathodic protection, plastics in corrosive service, corrosion metallurgy, underground corrosion (round table discussion).

Wednesday, May 22

9-12 noon—Laboratory inspection and demonstrations, Syracuse University, Department of Chemical and Metallurgical Engineering.
1:30-4:30 pm—Field demonstration and tours: Pipe line survey—Niagara Mohawk Power Corp.; chemical plant visit—Solvay Process Division; manufacturing plant—Carrier Corp.

Aircraft, Pulp and Marine Symposia For San Francisco

Symposia on aircraft and pulp and paper industry problems and on corrosion in marine environments have been added to the technical program for NACE's 1958 conference. The additions, announced by E. D. Verink, Aluminum Company of America, technical program chairman, will bring to 16 the number of symposia scheduled.

These are in addition to three educational lectures, and two round table sessions. Two days, Sunday March 16 and Monday, March 17 have been reserved for meetings of technical committees.

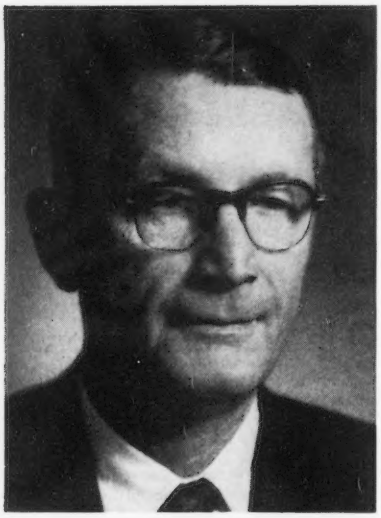
Mr. Verink is actively at work now seeking suitable technical papers.

Roger D. Loper, Standard Oil Co. of California, San Francisco, is general chairman of the conference.

NOTICE ON PAYMENT OF 1957 NACE DUES

Invoices for 1957 membership dues have been sent to all Acitve and Junior NACE members. These dues are payable January 1, 1957. The NACE by-laws state that no member with dues in arrears for three months shall receive the publications of the association until such dues are paid.

- ***Accordingly the names of Active and Junior members whose 1957 dues have not been received by March 30, 1957 will be removed from the mailing list to receive CORROSION. No mailings of CORROSION will be made to delinquent members until dues are paid.***



W. H. STEWART

L. L. WHITENECK

A. L. STEGNER

Stewart, Whiteneck, Stegner Elected to Offices Effective on Last Day of Conference

W. H. Stewart, Sun Pipe Line Co., Beaumont, Texas is the new president of the National Association of Corrosion Engineers. Mr. Stewart, elected with L. L. Whiteneck, Plicoflex, Inc., Los Angeles, Cal., vice-president and A. L. Stegner, Tennessee Gas Transmission Co., Houston, treasurer, will take office on the last day of the 13th Annual Conference.

Mr. Stewart was vice-president 1956-57. Mr. Stegner succeeds R. A. Brannon, Humble Pipe Line Co., who has served several years as NACE treasurer.

W. H. Stewart

Mr. Stewart, a member of the original group of pipe line engineers that formed the Mid-Continent Cathodic Protection Association, and now corrosion engineer for the Crude Lines Division, Sun Pipe Line Co. has been active in petroleum organizations dealing with corrosion for many years. He was for two years chairman of the Natural Gasoline Association's Condensate Well Corrosion Committee and is a member of the American Petroleum Institute's subcommittee on external corrosion.

First chairman of NACE's T-2 committee on Pipe Line Corrosion, he has agreed to continue until the committee's current project on minimum current requirements is completed. He joined Sun Oil Company in 1929 and Sun Pipe Line Co. in 1934. He was elected to the NACE Board in 1955 and vice-president in 1956.

L. L. Whiteneck

Now vice-president and director of corrosion control for Plicoflex, Inc., Los Angeles, he formerly was senior Harbor Engineer for the Long Beach, Cal. harbor department in charge of testing, evaluation and corrosion design.

He has had experience in water works design and design of mining developments in the Philippines. In NACE he has been an official of Western Region and was a member of the board of directors. He is chairman of T-6 and a member of ASTM.

A. L. Stegner

He is a director of the corrosion control program and radio communications department of Tennessee Gas Transmission Company and has been a member of the NACE board of directors for the past year. He has been with Tennessee Gas since 1946, when he returned from service. A graduate of Louisiana State University in electrical engineering, he worked in power transmission and distribution engineering from his graduation in 1928 until he entered service in 1941. He is a member of and active in several other engineering societies in addition to NACE.

Magoffin Installed As Western Region Chairman

At a joint meeting of Los Angeles Section and Western Region Division of NACE January 23, new regional officers were installed as follows: L. E. Magoffin, California Water and Telephone Co., chairman; E. H. Tandy, Standard Oil Company of California, vice-chairman and D. P. Armbruster, San Diego Gas & Electric Company, secretary-treasurer. Sixty-four members attended the meeting.

New Directors Will Represent Corporate And Active Members

Brink

Kuster

Treseder

Three new directors will take office on the last day of the 13th Annual Conference. They are E. G. Brink, American Viscose Corporation, Philadelphia; Ralph E. Kuster, Union Gas Co. of Canada, Ltd., Chatham, Ont. and R. S. Treseder, Shell Development Co., Emeryville, Cal. Mr. Brink will represent active members while the other two will represent corporate members.

One vacancy remains to be filled by the NACE board of directors. It was created by the election of A. L. Stegner to the board.

E. G. Brink

Mr. Brink, active in NACE as chairman of Philadelphia Section and of Northeast Region, also is a member of and active in other organizations. He has a degree in chemical engineering from Rensslaer Polytechnic Institute (1934). He first worked on building waterproofing problems and then did research and development work in protective coatings for A. C. Horn Company and the paint division of Sinclair Refining Co. Since 1940 he has handled materials and corrosion problems for American Viscose.

Ralph E. Kuster

He is in charge of the corrosion control construction and training program for Union Gas Company of Canada. A graduate from University of Toronto in 1949 with a BASc in electrical engineering, he worked for Bell Telephone Company, specializing in stray current electrolysis of lead cables. He has been

(Continued on Page 106)

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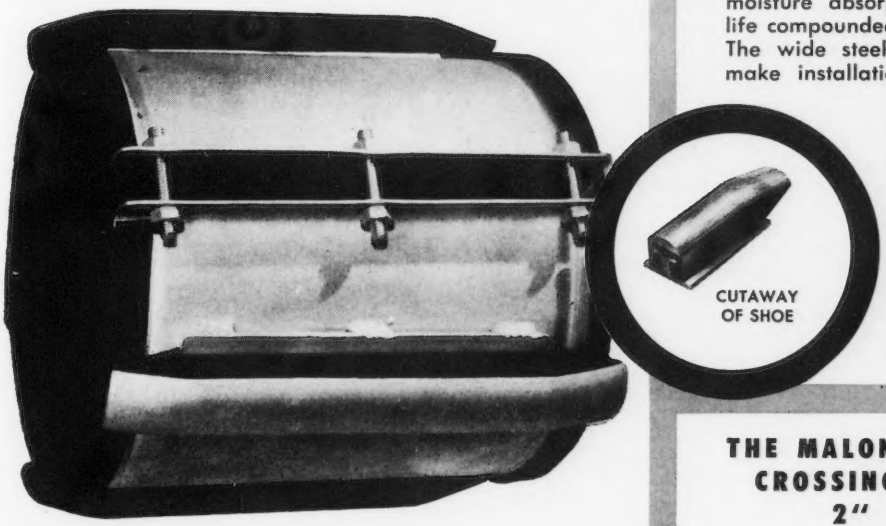

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Bonded metal-to-Neoprene-to-metal, the runner insulates and also permits flexibility to compensate for pipe shifting and acts as a shock absorber to prevent damage due to sudden heavy loads.

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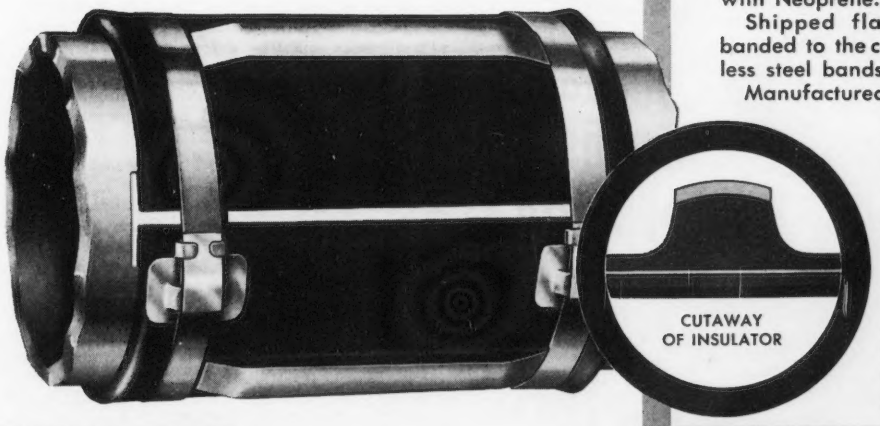

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Manufactured in sizes from 2" thru 12", it can be used either on installations where there is only one nominal pipe size difference or on installations having a larger differential.

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Automatic Cathodic Protection Control Is Topic at San Diego

San Diego Section met January 28 at Lawton's Restaurant in La Mesa, California. Approximately 60 members and guests heard W. A. Bowen and E. R. Streed of the U. S. Navy Engineering Research and Evaluation Laboratory, Port Hueneme, California speak on Automatic Control of Cathodic Protection. Mr. Bowen described various methods of automatic control of cathodic protection on Navy ships and by the use of slides, showed wiring diagrams of equipment. A miniature system was used as an aid in showing actual control and the need for it. Slides also were shown of a new pilot model full-size automatic controller which makes complete adjustment to maintain a fixed voltage impressed on the anodes, within the time specified by the Navy, using magnetic induction as the basic control.

During the business meeting new officers of the section for 1957 were presented as follows: Dan Nordstrom, The Gates Rubber Company chairman; L. L. Flor, vice-chairman and Kenneth R. Christy, Federal Housing Administration, secretary-treasurer.

VanNouhuys Reappointed

H. C. Van Nouhuys, Southeastern Pipe Line Co., Atlanta has accepted appointment for another year to the position of chairman of the Regional Management Committee.

Lehigh Valley Section Hears Paint Discussion

At the January 21 meeting of Lehigh Valley Section at Howard Johnson's Restaurant, Allentown, Pennsylvania approximately 20 members and guests heard Francis Scofield of the National Paint, Varnish & Lacquer Association speak on Paints as Corrosive Control Media. Mr. Scofield discussed two general classifications of paints: Solvent thinned and water-thinned types, and the general properties of each. Mr. Scofield pointed out the main criteria for corrosion control are proper surface preparation and proper thickness of paint. The basic method of surface preparation is sandblasting.

Following Mr. Scofield's presentation, it was announced the next meeting of the Lehigh Valley Section would be at the Wyomissing Club in Reading, Pennsylvania on March 18. T. P. May, International Nickel Company, Inc. will speak on Fretting Corrosion.

North Central Region's By-Laws Are Approved

Rules and by-laws of North Central Region, distributed October 22 to regional members with a letter signed by E. V. Ivanso were approved by the board of directors of the National Association of Corrosion Engineers at its December meeting.

•

The 10-Year Index to CORROSION now available has more than 4000 reference phrases.

1958 Awards Committee Members Are Named

The following have been named to the 1958 Awards Committee: W. F. Fair, Jr., chairman; Ivy M. Parker, Norman Hackerman, R. M. Wainwright, H. P. Godard, S. K. Coburn, C. G. Munger, George E. Best and K. G. Compton. All are well known from their long activity in NACE affairs.

New Directors Will—

(Continued From Page 104)

active as an officer of the Southern Ontario Committee on Electrolysis, is a member of T-2H, secretary-treasurer of Canadian Region and a member of corrosion control committees in the American Gas Association.

He served five years in the Royal Canadian Air Force during World War II.

R. S. Treseder

For more than 15 years Mr. Treseder has been employed by Shell Development Co., Emeryville, Cal. investigating corrosion problems of petroleum and chemical industries. He is now Development Supervisor, Materials Engineering and Corrosion Department. He has a BS in chemical engineering, University of Utah.

He has been very active in NACE affairs, in technical committee work, as an officer in Western Region and San Francisco Bay Section, a member of the Awards Committee; a member of the Editorial Review Sub-Committee and has published many papers on corrosion. He is sought after as a lecturer at corrosion courses.

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Oklahoma U-Central Oklahoma Section's Short Course Schedules Twenty-Six Sessions

Twenty-six sessions are on the program of the Fourth Corrosion Control Short Course to be given April 2-4 at the University of Oklahoma, Norman. The course is sponsored jointly by Central Oklahoma Section NACE and the university. Principal attention will be given to corrosion problems associated with the petroleum industry.

The tentative program and names of confirmed speakers follows:

Tuesday, April 2

Morning—R. V. James, University of Oklahoma, chairman.

Welcome—Lloyd E. Swearingen, University of Oklahoma.

Program and achievements of NACE.

Fundamentals of Corrosion.

Afternoon—Use of Inhibitors in Petroleum Production, R. G. Bechtell, Gulf Oil Corp.

Field Application of Inhibitors in Western Kansas, Dewey Peterson, Cities Service Oil Co.

Corrosion in Condensate Wells, Elk City Field, Hollis B. Carlyle, Shell Oil Co.

Use of Inhibitors in West Texas, Harold Winston, Gulf Oil Co.

Laboratory Evaluation of Inhibitors, E. J. Simmons, Sun Oil Co.

Afternoon—Transportation and Processing, Frank B. Burns, Kerr-McGee Industries, chairman.

Economical Design of an External Coating System for a Pipe Line.

Evaluation of Pipe Line Coatings.

Internal Coating of Pipe Lines, John C. Watts, Jr., Internal Pipe Line Maintenance Co.

Corrosion Problems in Process Industry.

Wednesday, April 3

Morning—Measurement of Corrosion, M. L. Steffens, Oklahoma Natural Gas Co., chairman.

Instruments for Measuring Corrosion.

Survey of Literature on Radioactive Techniques, W. R. Upthegrove, University of Oklahoma.

Corrosion Monitoring in Refinery Equipment.

Current Practice in Measuring Corrosion in Tubing, Donald F. Taylor, Jr., Otis Pressure Control, Inc.

Afternoon—Petroleum Production, Yale W. Titterington, Corrosion Services, Inc.

Corrosion Problems in Oil Well Casings, J. E. Landers, Continental Oil Co.

Cathodic Protection of Surface Equipment, C. O. Smith, Carter Oil Co.

Corrosion Control Design in Salt Water Disposal, Benjamin I. Routh, Rice Engineering and Operating Co.

Corrosion Problems in Water Flood, Ray W. Amstutz, Earlougher Engineering Co.

Afternoon—Transportation and Processing, O. W. Everett, Oklahoma Natural Gas Co., chairman.

Cathodic Protection—When, Where and How Much, Ted L. Canfield, Cathodic Protection Service.

Sacrificial Anodes for Pipe Line Corrosion Control, P. F. George, Dow Chemical Co.

Rectifiers for Corrosion Control.

Corrosion Problems in a Refinery.

Thursday, April 4

Morning—Dan H. Carpenter, Aquaness Div., Atlas Powder Co., chairman.

Factory Made Plastic Lined Pipe, D. C. Neely, Spang Chalfant Div., National Supply Co.

Tim-Coat, P. H. Timothy, Southern Production Co., Inc.

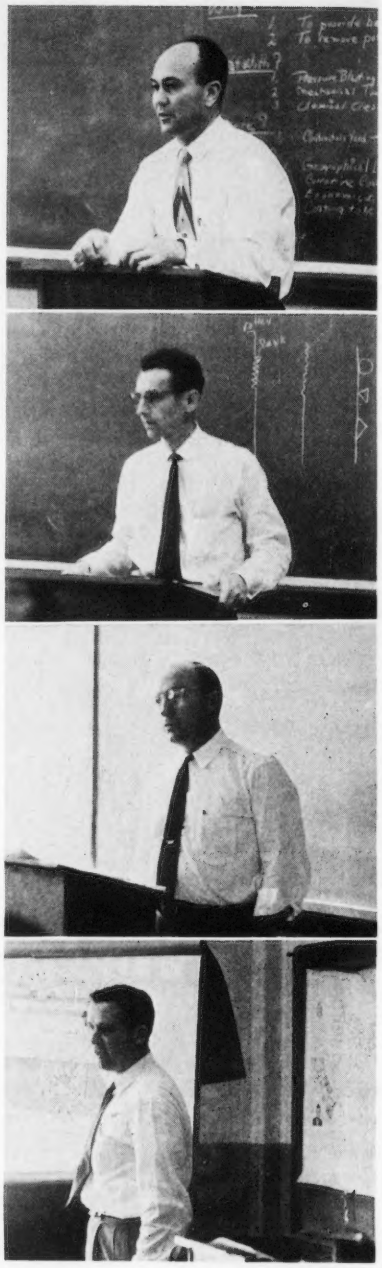
Biological Corrosion, Carl Oppenheimer, Pan American Oil Co.

Developments in the Control of Telephone Cable Corrosion, Lamoine D. Weiser, Southwestern Bell Telephone Co.

Afternoon—Petroleum Production Section, R. G. Bechtell, chairman.

Progress Report on the Use of Plastics for Combating Corrosion, H. D. Boggs, Fibercast Corp.

Petroleum Production Round Table: R. G. Bechtell, moderator, with speakers on allied subjects.



FOUR OF TEN INSTRUCTORS at the Houston Section Short Course January 31-February 1 at University of Houston are shown at work above: (Top to bottom) Ed Oakes, Houston Clemtex, Inc.; L. G. Sharpe, Napko Paint Company; P. R. Butterfield, Transcontinental Gas Pipe Line Corp.; M. A. Riordan, Rio Engineering Co., all of Houston.

Improvements to Be Made In Houston Short Course

Improvements will be made in the next corrosion short course to be given by Houston Section. Suggestions from persons attending the January 31-February 1 course at University of Houston are being weighed. The course attracted

(Continued on Page 110)

APEX for cathodic protection

MAGNESIUM ANODES

Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

Anode folders or technical consultation with our engineers available upon request.

APEX Anodes are available in 17 lb. and 32 lb. bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.

APEX SMELTING COMPANY

CHICAGO CLEVELAND LOS ANGELES

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U.S.I. CHEMICAL NEWS

A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries

Greenleaf to Handle Market Development of Zirconium And Titanium for U.S.I.

William C. Greenleaf has been named Manager of Metals Development for U.S.I. and will be responsible for market development and sales of zirconium and titanium sponge, to be produced from U.S.I.'s two new plants now being built in Ashtabula, Ohio.

A recognized authority in the field of zirconium and titanium, Mr. Greenleaf presented three papers during the 1955 Atomic Industrial Forum Zirconium Program, describing (1) melting of zirconium, (2) fabrication of zirconium, and (3) zirconium mill products and prices. He also conceived and developed processes now in general use for producing both wide-sheet and flat-bar titanium and zirconium by continuous strip-mill techniques.

Faye Named Manager of Sodium Product Sales

Martin Faye has been named Manager of Sodium Product Sales for U.S.I. and will be responsible for coordinating sales and sales promotional activities for metallic sodium, "U.S.I. Isosebacic" acid and related products.

Mr. Faye joined the U.S.I.-National Distillers organization in 1952 in the Market Research and Development Department.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing the Editor, U.S.I. Chemical News.

A zirconium-copper alloy now available is reported to combine high electrical conductivity with good strength retention at elevated temperatures. Suggested for electrical motor commutators serving above 500°F where strength is needed. Conductivity is 95.8% of copper. **No.1193**

Titanium wire cloth is now on the market in sizes from 60 mesh to coarser grades. It is reported to be particularly suitable for filtering or screening highly corrosive materials. **No. 1197**

Zirconium and Titanium Lick Roughest Corrosion Problems

Metals to be Available at Lower Cost in Future; Provide Long-Lived Materials of Construction; Complement Each Other on Corrosion Resistance

It is now practical to fabricate equipment which is *corrosion-resistant to almost every substance encountered in industry*, by using either zirconium or titanium metal. Alloys of either metal, or possibly both, may extend the range even further.

Industrial applications of these metals have been hampered by two considerations: availability and price. Zirconium will shortly be produced at a rate sufficient to supply industrial needs, and titanium has been available to industry during the past two years. And it is expected that increased production of these metals during the next few years will result in significant price decreases.

Twelve to thirteen thousand tons of titanium were available in 1956 and present construction schedules indicate that the figure will rise substantially in 1957. U.S.I.'s new plant alone will add 5,000 tons to the annual production capacity by the end of the year. Zirconium will be on the market in quantity by mid-1957. When its new plant at Ashtabula, Ohio gets under way, U.S.I. will be able to supply 500,000 pounds or more per year to commercial users in addition to its Atomic Energy Commission commitments of 1,000,000 pounds per year.

New Metals Economical

Chemical process equipment can now be fabricated from titanium for a little over twice the price of stainless steel, and it is expected that in the future titanium equipment will be only 50-75% higher than stainless. Commercial grade zirconium equipment will probably be priced only 75-100% higher than stainless when volume production is reached.

Typical Corrosion Resistances* of Zirconium and Titanium

Corrosive Media	Metal Resistance	
	Zirconium	Titanium
Sulfuric Acid	excellent to good below 80%	good below 5%
Nitric Acid	excellent	excellent
Hydrochloric Acid	excellent	good below 10%
Phosphoric Acid	excellent to fair below 85%	poor
Chromic Acid	excellent	excellent to good
Aqua Regia	poor	excellent
Wet Chlorine Gas	poor	excellent
Chlorine Water	excellent	excellent
Sodium Hydroxide	good below 90%	good below 50%
Ferric Chloride	poor	excellent
Calcium Chloride	excellent	excellent
Cupric Chloride	poor	excellent
Sodium Chloride	excellent	excellent
Ammonium Chloride	excellent	excellent
Aluminum Chloride	excellent	excellent to fair

*Above data do not cover all conditions because of space limitations. Literature references may be obtained by writing the Editor, U.S.I. Chemical News, 99 Park Ave., N. Y. 16, N. Y.

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Division of National Distillers Products Corporation
99 Park Avenue, New York 16, N. Y.

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NEW TROPOXIES
Have greater resistance to
CORROSIVE CHEMICALS

Correct Mil Thickness Applied Within Hours

Ordinary paints "give up" when chemicals or chemical fumes attack. New Tropoxy enamels, for both moderate and severe conditions, give long-lasting protection to exterior metal, wood, concrete, plaster, brick, cement or cinder block. They are color-fast, and the ideal 5-mil thickness can be built up within hours.

Protective Coatings for Corrosion Problems

Investigate our oleoresinous phenolics, rubber-base paints and enamels, high-heat (up to 1000°) aluminums. They have been performance-proved on thousands of applications.

FREE—complete information on our specialized industrial coatings sent on request.

TROPICAL PAINT CO.
1142-1278 W. 70th, Cleveland 2, Ohio
Heavy-Duty Maintenance Paints Since 1883

TROPICAL
SUBSIDIARY OF PARKER RUST PROOF COMPANY

Teche Section Plans June 6-7 Corrosion Course at Lafayette

Teche Section has scheduled a Short Course on Corrosion to be held at Lafayette, La. on June 6-7. Sessions will be in the new Southwestern Louisiana Institute engineering building. Max I. Suchanek, Dowell, Inc., Lafayette is general chairman of the course.

The program will be designed to cover oil and gas well corrosion, offshore corrosion problems and pipeline protection methods. Speakers will come from major oil companies and laboratories in the area.

A fee of $15 has been established for the course, to cover two lunches at the university cafeteria and an evening banquet at the Lafayette Petroleum Club. Preregistrations will be accepted by Mr. Wayne Grant, The Texas Company, Production Department, P. O. Box 457, New Iberia, La.

The section held its annual ladies' night January 24 and installed officers.

Nine Meetings Scheduled By Shreveport Section

Shreveport Section has scheduled nine meetings March 5 through January, 1958. All meetings are to be held at the Washington Youree Hotel, Shreveport. A fellowship hour is followed by dinner.

The schedule follows:
March 5—Coatings.
April 2—Review of national NACE meeting papers, Ned Stearns, moderator.
May 7—Inspection, D. E. Stearns.
June 4—Cathodic protection.
September 3—Barbecue or social.
October 1—Well corrosion.
November 5—Instruments.
December 3—Cathodic protection.
January 7—Testing or economics.

Cavitation Discussed at Detroit Section Meeting

Approximately 26 members and guests attended the January 24 meeting of Detroit Section to hear A. J. Thompson, Allis-Chalmers Manufacturing Company talk on "Cavitation and Impingement Attack in Pumps."

•

Organizations of corrosion engineers have been founded in England, France, Germany, Italy, Australia and Japan since NACE was established.

NACE Has No Copies Of Conference Papers

No copies of papers presented at the 13th Annual Conference are available from NACE. Authors of papers sometimes prepare preprint versions of their papers in which cases copies may be secured from authors. Persons interested in technical material presented are urged to consult CORROSION in which all papers approved by the NACE Editorial Review Subcommittee and the editor of CORROSION will be published after they are approved. Non-members of NACE may subscribe to CORROSION at rates indicated in this issue.

NACE MEETINGS CALENDAR

March

4 North Texas Section, Dallas. Design for Corrosion, F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis.
5 Houston Section.
7 Pittsburgh Section. Tour of U. S. Steel Corp. Research Center.
18 Lehigh Valley Section, Keystone Trail Inn, Allentown, Pa. Fretting Corrosion, T. P. May, International Nickel Co., Inc. (Tentative)
19 Cleveland Section. Copper and Its Alloys, Including Aluminum Bronze for Use in Corrosive Environments, I. S. Levinson, Ampco Metals, Inc.
26 Central Oklahoma Section.
28 Sabine-Neches Section, Little Mexico Restaurant, Orange, Texas. Corrosion in Recirculating Cooling Water Systems.
28 Kanawha Valley Section, Kanawha County Airport, Charleston, W. Va. Report on Kanawha Valley Coordinating Committee on Corrosion and round table discussion on cathodic protection.

April

1 North Texas Section. How to Evaluate Corrosion Inhibitors, Jay Simmons, Sun Oil Co., Dallas. At Fort Worth.
2 Shreveport Section. Review of NACE meeting papers, Ned Stearns, D. E. Stearns Co., Washington-Youree Hotel.
4 Pittsburgh Section. Mellon Institute.
16 Chicago Section. Internal Corrosion and Its Measurement, G. A. Marsh, Pure Oil Co., Crystal Lake, Ill.
16 Cleveland Section. Atmospheric Corrosion, R. B. Hoxeng, U. S. Steel Corp.
18 Detroit Section. Industrial Maintenance Paint Development, S. L. Gajownik, Sherwin-Williams Paint Co. Dinner. Annual paint meeting.
23 Central Oklahoma Section.
25 Sabine-Neches Section. Protective Coatings panel. Little Mexico Restaurant, Orange, Texas.

Improvements to Be–

(Continued From Page 108)

79 paid registrants and two students, according to W. P. Noser, Humble Pipe Line Co., Houston, in charge of registration.

Two things were unique about the course. It was the first Houston Section course at which the round robin technique was employed: Groups of students rotated among the instructors, who repeated their material. Also it was the first in which registrants were divided roughly on occupational lines. The aim was to achieve a greater flexibility in instruction.

It is the announced aim of Houston Section to prepare a printed version of the course content to be given to each registrant.

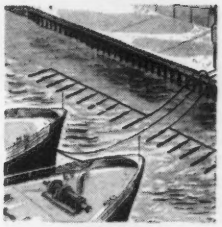
NATIONAL TRADE-MARK GRAPHITE ANODES

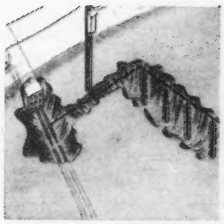
GIVE *LASTING*

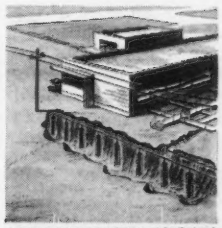
Cathodic Protection

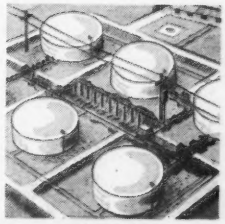
There can be no doubt as to the effectiveness of cathodic protection in today's fight against corrosion of buried or submerged metal structures. But how *permanent* is the protective system itself? Impressed current systems, using **"National" graphite ground anodes,** give more positive, flexible, trouble-free and *lasting* protection than any other type.

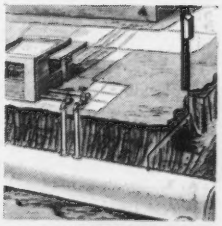
MANY "NATIONAL" GRAPHITE INSTALLATIONS ARE 20 YEARS OLD AND STILL GOING STRONG! Put in "National" graphite anodes and they're there to stay. One look at the rectifier gives top-side evidence that they're working — how much current they're discharging and at what voltage. Consult National Carbon Company or one of the many engineering firms specializing in corrosion prevention. Discover this *modern* way to combat one of industry's most costly enemies.


SHIP HULLS


LEAD-COVERED CABLES


PIPE-LINE BOOSTER STATIONS


TANK FARMS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WHAT WILL YOUR PIPE LINES LOOK LIKE 10 YEARS FROM NOW ?

In case after case, lines protected with TAPECOAT have been dug up after more than 10 years of service *with no signs of deterioration on the pipe surfaces uncovered.* That's why TAPECOAT coal tar coating is specified by those who realize that continuing protection is the *first* consideration.

Since 1941, this quality coal tar coating in handy tape form has demonstrated its ability to withstand corrosion year after year, above and below ground, on pipe, pipe joints, couplings and other vulnerable surfaces.

Why gamble with "unknown" protection? By using TAPECOAT, you'll be sure to have the quality protection you need for long service life without costly maintenance and replacement.

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Originators of Coal Tar Coating in Tape Form

1521 Lyons Street
Evanston, Illinois

Railway Tank Car Safety Hazards Chicago Topic

Safety hazards involved in the transportation of chemicals in railway tank cars were emphasized by J. Robert Spraul, General American Transportation Company, at a meeting of Chicago Section January 15. About 70 members and guests were present to hear his talk titled "Corrosion Problems in Transportation Vehicles."

H. C. Boone, Peoples Gas Light & Coke Co., section secretary reported that the section now has 344 active and 29 corporate members. I. J. Acosta, Crane Co., was master of ceremonies and the fellowship hour, sponsored by Duriron Co. had Wendell A. Watkins and John Haddick as hosts.

Mr. Spraul said that no corrosion can be tolerated in railway tank cars because of the possibility a leak may occur during a stopover where persons responsible would be unable to cope with the resultant dangers. More than 700 commodities are being transported now in tank cars, he said.

Difficulties in electroplating insides of tank cars were commented on, the result being that other coatings used make it necessary to carefully consider cleaning methods.

A vigorous question and answer period followed the illustrated talk.

Plastics Discussion Held By New York Section

"Project Plastics," a panel discussion, was held by Metropolitan New York Section at its January 16 meeting. Properties of furans, phenolics, polyesters, epoxies, fluorocarbons and polyvinylidene chloride were discussed.

Raymond A. Dittbrenner, Carboline Co., was moderator of a panel consisting of E. P. Mampe, Haveg Corp.; R. E. Gackenbach, American Cyanamid Corp.; L. J. Fitzharris, M. W. Kellogg Co. and W. J. Osborn, Arbonite Corp.

The section meets next April 17.

British Laboratory Adopts NACE Abstract Filing Guide

Chemical Research Laboratory, Teddington, Middlesex, England uses an adaptation of the NACE Abstract Filing System to classify and index its literature. The system developed at the library under the direction of Miss D. M. Brasher, consists of the NACE index, revised and expanded to include subject headings in W. H. J. Vernon's "Bibliography of Metallic Corrosion."

Details of the revised system and instructions about its use are covered in a publication "Classification of Topics Related to Corrosion," published by the Department of Scientific and Industrial Research. The British system does not involve the use of semi-automatic sorting by means of punch cards, but provides duplicate cards for each additional topical reference.

Hackerman Is Re-Named

Norman Hackerman, University of Texas, Austin has been reappointed to another term as chairman of the NACE Education Committee. This committee coordinates the educational activities in which the association participates.

NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.

May 20-22—Northeast Region Corrosion Control Conference, Syracuse University, Syracuse, N. Y.

Oct. 1-4—North Central Region, Chicago, Sherman Hotel. Exhibition.

Oct. 1-4—South Central Region, Oklahoma City, municipal auditorium. Exhibition.

Nov. 12-14—Northeast Region Fall meeting, Pittsburgh, Pa.. Penn-Sheraton Hotel.

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

October 5-8—Northeast Region, Somerset Hotel, Boston, Mass.

October 20-24—South Central Region. New Orleans, Roosevelt Hotel.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

SHORT COURSES

April 2-4—University of Oklahoma, Norman and Central Oklahoma Section NACE.

June 6-7—Teche Section Short Course on corrosion. Southwestern Louisiana Institute, Lafayette, La.

Metallurgists Are Sought By Naval Air Center

Metallurgists to perform work in connection with the development of high strength steels, precision castings, heat resistant alloys, inert and shielded metal arc welding or other equipment used in the manufacture and operation of aircraft are sought for the Naval Air Experiment Center, Philadelphia, Pa. Salaries range from $4480 to $7035 per annum.

Interested persons who want the opportunity to work in one of the most modernly equipped centers in the country are asked to write or submit a Standard Form 57, Application for Federal Employment, to the Industrial Relations Dept., Naval Air Material Center, Naval Base, Philadelphia 12, Pa.

R. A. Brannon Talks on Corrosion Engineering

R. A. Brannon, Humble Pipe Line Co., Houston spoke to 25 members and 14 guests at a January 7 meeting of North Texas Section at Fort Worth. He said engineers need facilities adequate for this work and appropriate places in their companies' organizations.

Exhibitions will be held at NACE regional meetings in Oklahoma City and Chicago this fall.

Products from Anodes to Zirconium to Be Shown

St. Louis Exhibition To Be Largest Staged by NACE

What is sure to be the most diversified exhibition and at the same time the largest in number of booths and companies ever staged by NACE opens at St. Louis March 12. Persons attending the event at Kiel Auditorium during the NACE 13th Annual Conference will be able to see the latest in equipment materials, supplies and services available in the corrosion mitigation field.

A simple classification by principal products does not do full justice to the many things the corrosion engineer can see and handle. From the extremely simple galvanic anodes to the complex recording corrosion meter, a wide variety of equipment in metal, plastic and ceramic; sensitive electrical instruments; cleverly designed machines for the quick application of coatings and wrappings and plastic materials with complex formulations will be shown.

Listed below, grouped roughly according to principal products are most of the exhibitors at the conference:

AIR COMPRESSORS
Spray Equipment
Clementina, Ltd.
Gray Co., Inc.

ANODES
Carbon,
Light Metals, Zinc
Aluminum Company of America
American Zinc Sales Co.
Dow Chemical Company
Federated Metals Div.,
American Smelting & Ref. Co.
National Carbon Co.
Standard Magnesium Corp.

CATHODIC PROTECTION
Engineering and Materials
Brance-Krachy Co., Inc.
Cathodic Protection Service
Electro Rust-Proofing Corp.
Good-All Electric Mfg. Co.
Harco Corporation

COATINGS
Organic, Plastic
Amercoat Corp.
American-Marietta Co.
Carboline Company
Coast Paint & Lacquer Co.
Cook Paint & Varnish Co.
Dampney Co.
Glidden Co.
Inertol Co.
Landau, J., Co.
Metal and Thermit Co.
Mobay Chemical Co.
Pittsburgh Coke & Chemical Co.
Rust-Oleum Corp.
Socony Paint Products Co.
Steelcote Manufacturing Co.
Tresco, Inc.
Truscon Laboratories
U. S. Stoneware Co.

COATINGS
Metallic
Chicago Metallizing Corp.
General American Transportation Corp.
Metallizing Engineering Co.
St. Louis Metallizing Co.

CONNECTORS
Electrical
Burndy Corp.

GLASS-LINED EQUIPMENT
Pfaudler Co.
Smith, A. O., Corp.

INHIBITORS
Armour Chemical Div.
Atlas Powder Company
Deady Chemical Co.
Dearborn Chemical Co.
Monsanto Chemical Co.
Pfizer, Chas. & Co., Inc.
Shell Oil Company
Tretolite Company
Visco Products Co., Inc.

VISIT NACE BOOTH FOR INFORMATION

Publications and services of the National Association of Corrosion Engineers will be shown at the NACE booth at the St. Louis Exhibition in Kiel Auditorium. Persons interested in NACE will find:
1. Copies of NACE publications.
2. A display showing the advantages of the Corrosion Abstract Card Service.
3. Information about membership.
4. A representative of NACE to answer questions.

INSTRUMENTS and TESTING
Cosasco Div., Perfect Circle Corp.
Crest Instrument Co.
Labline, Inc.
Miller, M. C.
South Florida Test Service
Tinker & Rasor

PIPE COATINGS, WRAPPING and EQUIPMENT
American Coating & Supply Co.
Barrett Division,
Allied Chemical & Dye Corp.
Betzel, A. E., Engineering Corp.
Carey, Philip, Mfg. Co.
Crose, M. J., Mfg. Corp.
Crutcher-Rolfs-Cummings, Inc.
Dresser Mfg. Div.
Enamelex Corp. of Texas
Gulf States Asphalt Co.
Hill, Hubbell & Co.,
Div. General Paint Corp.
Holcombe Co., Inc.
Johns-Manville Sales Corp.
Kopners Co., Inc.
Middle West Coating & Supply
Midwestern Pipe Line Products Co.
Minnesota Mining & Mfg. Co.
Nicolet Industries, Inc.
Perrault Equipment Co.
Plicoflex, Inc.
Protecto Wrap Co.
Reilly Tar & Chemical Co.
Remco Mfg. Co.
Standard Pipeprotection, Inc.
Tapecoat Co.

PLASTICS
Construction Materials, Linings
Central Plastics Co.
Fibercast Corp.
Furane Plastics Inc.
Haveg Corp.
Kraloy Plastic Pipe Co., Inc.
Maloney, F. H., Co.
Plastic Products Co.
Saran Lined Pipe Co.
Shell Chemical Corp.
Shutt Process Equipment Corp.
Williamson, T. D., Inc.
Kellogg, M. W., Co.

PUMPS and VALVES
Alloy Steel Products Co.
Cameron Iron Works
Crane Company
Duriron Co., Inc.
Goulds Pumps, Inc.
Texsteam Corp.
Zopff Co.

STEEL, ALLOY
Process Equipment
Haynes-Stellite Co.
International Nickel Co., Inc.
Lukens Steel Co.
Nooter Corp.
Ryerson, Jos. T. & Son, Inc.

SURFACING, STEEL ALLOY
Alloy Surfaces Co.

TITANIUM
Republic Steel Corp.
Rem-Cru Titanium, Inc.

TUBES
Heat Exchanger
Phelps-Dodge Copper Products, Inc.

WOOD
Henry, F. & Sons, Ltd.

ZIRCONIUM
Carborundum Co.

Some Changes Made In Technical Program

Some revisions have been made in the technical program scheduled to be given during the NACE 13th Annual Conference and Exhibition at St. Louis March 11-15. Principal changes are:
1. Addition of another half-day session with four papers (some transferred from the General Corrosion Symposium) to the Refinery Industry Symposium. This symposium will have two sessions. (See complete program elsewhere in this issue.)
2. Papers were added to the General Corrosion Symposium to retain the two sessions scheduled originally (see February CORROSION, Page 100).
3. A paper has been added to the Corrosion Principles Symposium (see February CORROSION, Page 110) to make the total three. The added paper is the second part of a paper published earlier in CORROSION.

The remainder of the program is essentially the same.

Other information on the program has been published in CORROSION as follows:

January Issue

Soil Box Demonstration, List of Exhibitors and Women's Programs, Page 105.

February Issue

Registration Hours, Page 97.

Corporate Members' Luncheon, Banquet Program, Exhibition Hours, Page 98.

General Corrosion Symposium, Page 100.

Chemical Inhibitor Symposium, Page 108.

Corrosion Principles Symposium, Page 110.

Added Exhibitors, Page 112.

•

Papers are being sought now for NACE's 1958 Conference in San Francisco.

Note This Important St. Louis Meeting

It is important to NACE members to know what is going on in their association. The officers and directors of NACE urge all members to make a note of this important time and date:

Wednesday, March 13
11:30 a.m.
Kiel Auditorium
Assembly Hall No. 1
2nd Floor, Northeast

The association's 1957 General Business Meeting will be held at that time and place. All NACE members are urged to attend to hear reports by NACE president, treasurer, executive secretary, Technical Practices Committee chairman, Publication Committee chairman, Policy and Planning Committee chairman, Regional Management Committee chairman.

• ***Certain actions of the NACE Board of Directors will be submitted for ratification by the membership.***

Plan now to attend!

Carlson

Dravnieks

Freedman

Honkala

Lang

Mason

McGlasson

Meyer

Nelson

Renshaw

Riggs

Snair

Expanded Refinery Industry Symposium Now Has Eight Papers in Two Sessions

Four papers have been added to the Refinery Industry Symposium, bringing the total to eight and adding another session. Some papers were transferred from the General Corrosion Symposium and others were added. The symposium will be given at two sessions, 2 to 4:30 pm March 12 and 9 to 11:20 am, March 13 during the NACE 13th Annual Conference at Kiel Auditorium, St. Louis.

Subject matter includes corrosion by jet fuels, amine gas treating solutions, acid corrosion, iron in hydrogen sulfide environments, sulfide corrosion cracking, condenser tube failures and properties of new alloy steels.

Quantitative Comparison of the Effects of Heat Treatment of Stainless Steels Corroded by Jet Fuels by R. G. Carlson, General Electric Co., Cleveland, Ohio.

Samples from free machining AISI 440C stainless steel were hardened and tempered identically at 16 tempering temperatures. Samples were given grit blast, chro honed, ball burnished, ground and carborundum blast surface finishes. After weighing samples were subjected to an environment of JP-4 fuel and water, removed at varying times, cleaned and weighed again. Weight losses were compared among different tempering temperatures and surface finishes.

Tests showed steel should not be heated over 400 C and the order of corrosion resistance was proportional to surface roughness of finishes as follows: ground, ball burnished, carborundum blast, chro honed and grit blast.

Corrosion in Amine Gas Treating Solutions by Frances S. Lang and J. F. Mason, Jr., The International Nickel Co., Inc., New York.

Corrosion tests were conducted in the laboratory on steel, stainless stee s, Monel and nickel in amine solution saturated with carbon dioxide and hydrogen sulfide. The effects of temperature, pressure and amine concentration and the presence of sludge were explored. Types 304 and 316 stainless steel gave consistently low corrosion rates under all conditions. Monel was satisfactory when carbon dioxide or hydrogen sulfide were present singularly in the amine but mixtures of the gases were damaging. Hydrogen sulfide alone in amine solution was not highly corrosive to any of the alloys. Corrosion increased with increase in severity of conditions.

Results of a number of field corrosion tests in operating equipment under a variety of conditions of temperature and concentration are given together with an interpretation of the data in the light of practical experience.

Corrosion Monitoring in Refinery Equipment by A. J. Freedman, E. S. Troscinski and A. Dravnieks, Standard Oil Company (Indiana).

A new corrosion test system based on the Indiana Conductometric Method permits continuous monitoring of corrosion rates in refinery equipment without interrupting normal operations. Corrosion decreases the cross-section, and consequently the electrical conductivity, of a metal specimen exposed to refinery fluids at high temperatures and remote locations. From the decrease in conductivity, the amount of corrosion which occurs between measurements can be determined. The system has been used successfully under all conditions of temperature and pressure encountered in a refinery. It has measured corrosion rates in vapor and liquid phases, with both oil and aqueous media.

With the aid of the corrosion probe, corrosion rates in operating refinery equipment have been determined quantitatively in a few hours' time as compared with months required for coupon measurements, water analyses and unit inspections. Refinery corrosion inhibitors have been compared rapidly in actual use. Effects of changes in unit operating procedures upon corrosion rates have been observed shortly after the changes were made. Sensitive locations where corrosion is expected have been monitored continuously. Excellent correlation of laboratory and field results has been obtained with the conductometric method.

Prevention of Localized Corrosion in Acid Handling Equipment by G. A. Nelson, Shell Development Co., Emeryville, Cal.

Accelerated corrosion in areas adjacent to welds in steel equipment handling sulfuric acid has been a constant problem in acid handling plants. The corrosion is usually in the form of deep grooves, which penetrate the steel at an advanced rate, causing retirement of equipment before the normal life has been attained, as judged by the thickness of the adjacent steel. This paper summarizes the results of field tests to determine the causes for the localized corrosion and to enumerate possible remedial measures to eliminate it. As a result of the work to date, it appears that the corrosion is due to differences in carbide structure created during welding or hot riveting operations. Possible remedies are to 1) remove the objectionable zones by a normalizing heat treatment, 2)

(Continued on Page 116)

Sudbury

Troscinski

Wright

BIOGRAPHIES

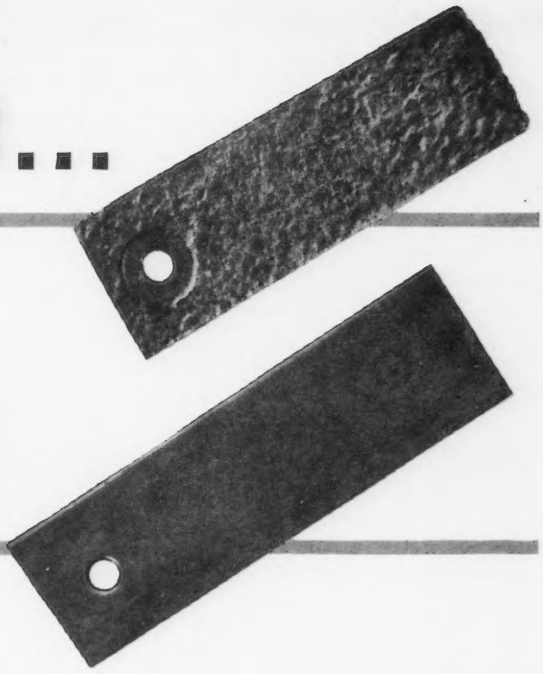
R. G. CARLSON—A metallurgist at the Refractory Metals Laboratory, General Electric Company, Cleveland. He has worked in General Electric's Research Laboratory in Schenectady and as a metallurgical engineer in the Aeronautics and Ordnance Divisions. He has a BMetE (1951) from Polytechnic Institute of Brooklyn and a MMetE (1955) from Rensselaer Polytechnic Institute.

A. DRAVNIEKS—Head of the Corrosion Section, Materials Division of the Engineering Research Department, Standard Oil Company (Indiana). He attended the University of Latvia and Marburg University, Germany, and received a PhD in 1949 from Illinois Institute of Technology. He has done work in the fields of paint technology, polarography, surface chemistry, and the kinetics of corrosion processes.

A. J. FREEDMAN—Project Engineer in the Corrosion Section, Materials Division of the Engineering Research Department, Standard Oil Company (Indiana),

(Continued on Page 116)

before...



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1 mil=.001 inch. A corrosion rate of 216 mils per year means that the corrosive attack, if uniform, would have corroded away the entire surface of the metal to a depth of .216 inches in a year. However, the real danger of high corrosion rates, as the coupon shows, is the much deeper and faster penetration occurring at localized areas.

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(Continued From Page 114)

prevent objectionable phases from forming, or 3) cover the areas with other corrosion resistant materials.

Corrosion of Iron by Solid Solutions in Its Sulfides by F. H. Meyer, O. L. Riggs, R. L. McGlasson and J. D. Sudbury.

An end product of the corrosion of iron in aqueous H_2S media has been recently identified as a crystalline material, Fe_9S_8 (Kansite). Kansite appears to form as a terminal product from a sequence of discrete iron sulfides—pyrites, marcasite, melnikovite, smythite, pyrrhotite, troilite and hydrotroilite—which develop from the continuous solid solution of iron and/or sulfur with a preceding or succeeding sulfide member of the sequence.

The formation of sulfides increasingly rich in iron cannot be explained satisfactorily by the electrochemical theory of corrosion. This theory fails also to account for the acceleration of H_2S corrosion due to the formation of corrosion scales.

Solid solution of iron in iron sulfide products of electrochemical corrosion is presumed by the authors to provide a secondary corrosion source in addition to the established electrochemical corrosion source. The rates of diffusion of iron sulfides will be intensified because some, and possibly all, of them are defective structures.

This kind of postulated mechanism has been used previously to describe the solid solution of iron into and diffusion through iron oxide corrosion products in high temperature oxidation systems. The outcome in this case, too, is a multiple layer formation of a sequence of discrete iron oxides; here, however, subsequent layers become increasingly poor in iron.

The validity of the hypothesis concerning a secondary H_2S corrosion source was checked by determining the corrosion rates of mild steel specimens treated with dry sulfides.

Corrosion Resisting Properties of the New Chromium-Nickel-Manganese Austenitic Stainless Steels by W. G. Renshaw and G. L. Snair, Jr., Allegheny Ludlum Steel Corp.

New chromium-manganese-nickel austenitic stainless steels of the AISI 200 series have properties including corrosion resistance nearly equivalent to the familiar chromium-nickel alloys of the 300 series. Developed to conserve nickel, the new alloys spread available nickel supplies about twice as far, the manganese and nitrogen compensating for the nickel saved.

For maximum corrosion resistance chromium content is maintained above approximately 17 percent and tests indicate a minimum of about 3½ percent nickel is required. Carbon content is set nominally at 0.15 percent maximum.

Data from tests under mild, intermediate and severe corrosive environments are reported and evaluated showing the new alloys compare favorably with the 300 series, indicating suitability for most applications except extreme chemical service. Resistance to heavily contaminated industrial atmospheres is excellent.

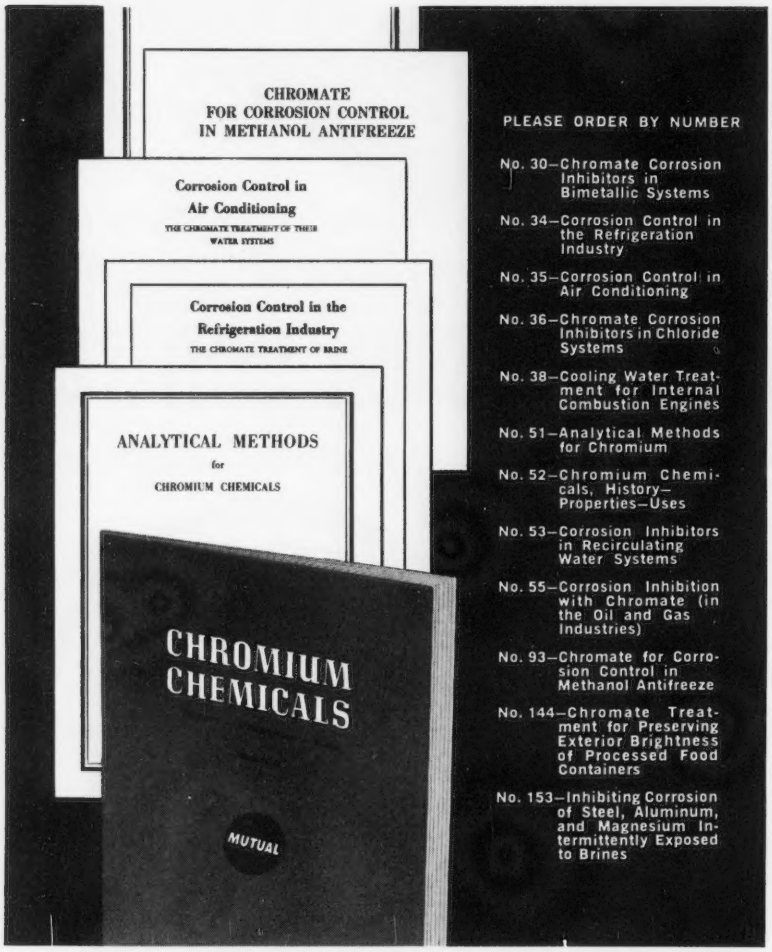
Under stress corrosion conditions behavior similar to 300 series can be expected. Resistance to localized attack is slightly lower and intergranular attack can be prevented by controlling carbon content which actually is less critical than in the 300 series. Compositions are in sight which will give superior performance in highly corrosive environments such as boiling nitric acid or salt spray.

Sulfide Corrosion Cracking of High Strength Bolting Material by Donald Warren and G. W. Beckman, E. I. duPont de Nemours & Co., Inc.

The sulfide corrosion cracking behavior of Type 4140 bolts was studied in H_2S-H_2O systems at temperatures of 20 to 120 C and at pressures of 1 to 17 atmospheres. The susceptibility to cracking increased with increasing bolt hardness, increasing applied stress, increasing amounts of plastic deformation and decreasing test temperature. Other bolting materials such as Inconel, Inconel-X, K-Monel and annealed Type 316 stainless steel were completely resistant to sulfide corrosion cracking. The sulfide corrosion cracking of Type 4140 bolts is believed to be best explained on the basis of hydrogen embrittlement.

Failure of Steel-Admiralty Duplex Condenser Tubes by Hydrogen Penetration by H. E. Honkala and E. A. Wright, Wolverine Tube Division, Calumet & Hecla Co., Detroit.

The cause of rapid failure of steel-admiralty duplex condenser tubes in propane condensers was found to be due to the diffusion of atomic hydrogen through the steel tubes. These tubes were exposed to a considerable quantity of hydrogen sulfide gas and sufficient pressure was built up between the outer tube and the liner to cause the liners to collapse. These failures occurred within four weeks after the units were put into service. Tests were conducted to duplicate these failures in the laboratory. Tests also were made to study the pressure build-up rate of a volumeless cell in various corrosive atmospheres.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BIOGRAPHIES

(Continued From Page 114)

Whiting, Indiana. He received a PhD degree from New York University in 1948. Prior to joining Standard Oil Co. he did research work at the Massachusetts Institute of Technology, Los Alamos Scientific Laboratory, and the University of New Mexico.

H. E. HONKALA—Technical supervisor at Wolverine Tube Division's Decatur, Alabama plant for the past five years, he has been employed by the division for 10 years. A graduate of Michigan College of Mining and Technology with a BS in chemical engineering, he worked several years for Ford Motor Company and for five years was in the Industrial Facilities Section of Army Ordnance. He is a member of ASM and SAM.

FRANCES S. LANG—Research Chemist, Corrosion Section, Research Laboratory, The International Nickel Co., Inc., Bayonne, N. J. She has a BS in chemistry from University of North Carolina (1940) and a PhD in physical chemistry from New York University (1952). She has been with Inco since 1951.

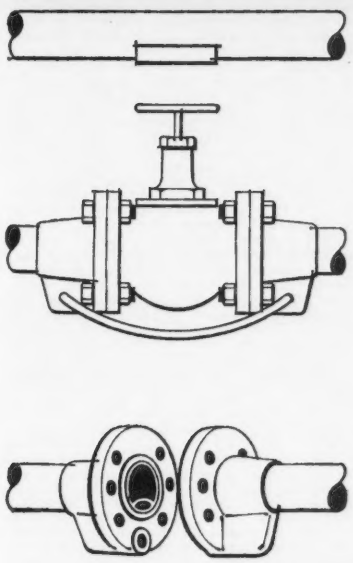
J. F. MASON, JR.—For 18 years a member of the Corrosion Engineering Section of The International Nickel Co., Inc. he has devoted himself to the study of metal corrosion in most industrial fields. He holds a BS in chemistry from Manahttan College, New York (1933) and attended the Chemical Engineering School of Brooklyn Polytechnic Institute for two years. He is author and co-author of numerous papers on metallic corrosion and widely known as a speaker on corrosion subjects.

ROBERT L. McGLASSON—A year's work in the quality control laboratory, Boeing Airplane Co., Wichita, Kan. aroused Mr. McGlasson's present interest in physical metallurgy. For the past four years a major portion of his work has been on corrosion metallurgy, with major emphasis on corrosion problems associated with oil production, as a metallurgist in the Development and Research Department of Continental Oil Co. He has a BS from Northwestern State College, Alva, Okla. in physics and mathematics.

(Continued on Page 120)

See the NEW ALCOA UNITRACE at the Corrosion Show . . . St. Louis, March 11-15
Bring your corrosion problems to the Alcoa Booth, No. 32 & 33!

With this new round shape, UNITRACE costs substantially less per foot. And since the steam passage has less outside wall area, external radiation heat loss is reduced. The need for thermal insulation is often eliminated. When insulation is used, it costs less because standard pre-formed pipe covering can be used.
to cut costs, boost efficiency of steam traced pipe...
ALCOA UNITRACE has a NEW SHAPE
for lower cost per foot... easier joining... less heat loss...better internal heat transfer



Sections of UNITRACE in the new shape can be easily and quickly joined by the weld and patch method (top). And a brand new UNITRACE flange—with product and steam passages cast as integral parts of the flange—simplifies installation of valves (center) and other flanged connections (bottom).

Want to save money on steam-traced piping? Here's good news for your pocketbook! ALCOA® UNITRACE *has a new cost-cutting shape* . . . a round section matching standard pipe shapes . . . available in 1½", 2", 3" and 4" sizes.

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The natural corrosion resistance of aluminum makes UNITRACE ideal for handling naval stores, molten sulfur, ammonium nitrate solutions, glacial acetic acid, fatty acids, tar, pitch, wax, urea and similar products which normally require heated transfer lines.

Find out today how *you* can use ALCOA UNITRACE to cut costs and improve efficiency of your heated transfer lines. Call your nearest Alcoa sales office, or write Aluminum Company of America, 892-C Alcoa Building, Pittsburgh 19, Pennsylvania.

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Chemical Industry Problems Covered By Eight Papers

Eight papers ranging in subject matter from heat transfer problems through coal chemical plant corrosion and featuring three papers on stress corrosion cracking of stainless steels will be given during the Chemical Industry Symposium at St. Louis. Sessions of the symposium are scheduled from 9 to 11:30 am on March 12 and 2 to 4:30 pm March 13 at Kiel Auditorium. The symposium is among the 13 to be given during the NACE 13th Annual Conference and Exhibition.

Abstracts of the papers follow:

Chemical Resistant Masonry Construction by Robert R. Pierce, Pennsylvania Salt Manufacturing Co., Philadelphia.

Fundamental and practical guides for the selection of materials and methods for good design are given as follows:

First, chemical resistance of brick materials and cements is described from a chemistry point of view. Inorganic materials are covered by a description of their constituents. Chemical resistance of organic materials is explained by showing the relation between corrosion resistance and molecular structure.

Second, five fundamentals of chemical resistant masonry engineering are outlined as guides for the design engineer. Practical experience guides are provided also for eight general types of construction, including drainage trenches, sumps, foundations and piers, process vessels, storage vessels, towers, neutralizers and clarifiers, and chimneys.

Third, chemical resistant masonry construction is discussed from the plant operators' point of view.

This paper is based on Pennsalt Chemicals' experience in manufacturing chemicals for 106 years combined with experience gained from recent corrosion studies at its 17 chemical plants.

Heat Transfer Through Coated Metal Surfaces by R. P. Lee, National Lead Co., South Amboy, N. J.

Coatings often are used to protect industrial heat transfer surfaces. However, efficient heat transfer is not always possible. This article was written to enable the corrosion engineer to choose those systems in which coatings can be used best. A mathematical analysis technique is provided together with laboratory data substantiating the method.

Use of Aluminum Alloys With Short Chain Aliphatic Acids by A. B. McKee and W. W. Binger, Aluminum Compaany of America, New Kensington, Pa.

Excellent suitability of aluminum alloys for handling short chain aliphatic acids and anhydrides has been demonstrated by extensive laboratory tests and has been confirmed by actual service experience covering many years. These acids, their anhydrides and their mixtures have been stored successfully, shipped and processed in aluminum storage tanks, heating coils, drums, tanks cars, piping, valves, stills, heat exchangers and reaction vessels. In addition to excellent resistance to corrosion, aluminum equipment has an added advantage in that it does not contaminate these products nor alter their water-white appearance.

Controlling Corrosion in Coal Chemical Plants by C. P. Larrabee and W. L. Mathay, U. S. Steel Corp., Monroeville, Pa.

Data are presented showing the types of constructional materials that are resistant to the many corrosive environments in coal chemical plants. Coal-handling equipment and processing equipment such as primary coolers, tar stills and light-oil stripping stills are discussed with regard to the mitigation of corrosion through the proper selection of materials and changes in process conditions. The protection of structural-steel work by paints is viewed from the standpoint of minimizing maintenance costs.

Some Case Histories of Stress Corrosion Cracking of Austenitic Stainless Steels Associated With Chlorides by H. R. Copson and C. F. Cheng, The International Nickel Co., Inc., Bayonne, N. J.

Some 22 case histories of stress corrosion cracking of Types 302, 304, 316, 321 and 347 stainless steels occurring in water, steam, brines and miscellaneous solutions are presented. In each case, either the chloride content was high initially or conditions favored chloride concentration. Temperatures usually were high, the environment often acid and in most cases it seemed likely that air was present.

Microexamination always revealed transcrystalline cracks which usually had characteristic branching growth.

In each case it was concluded that internal tensile stresses in combination with concentrated chlorides caused the cracking. Some means of avoiding cracking are pointed out.

Following case histories results of laboratory tests are presented which show that resistance to cracking increases with nickel content and that large additions of nickel bring about a major improvement. Inconel, at the high nickel end of this series of alloys is considered immune to this type of stress corrosion cracking.

Corrosion of Austenitic Stainless Steels in Sulfuric Acid by E. H. Phelps and D. C. Vreeland, U. S. Steel Corp., Monroeville, Pa.

The corrosion resistance of six different grades of stainless steel has been investigated in air-saturated and nitrogen-saturated sulfuric acid solutions at 30, 50 and 70 C. The results for the various grades are presented in terms of "active-passive" regions which depend on acid concentration, temperature and type of aeration. The use of potential measurements for the determination of the "active-passive" regions and the use of potential measurements in sulfuric acid plant equipment for detection of dangerous corrosion conditions, will also be discussed.

Effect of NO, HNO_2 and HNO_3 on Corrosion of Stainless Steel by H_2SO_4 by W. P. McKinnell, Jr., The Ohio Oil Co., Littleton, Col.; L. F. Lockwood, Dow Chemical Co., Midland, Mich. and R. Speiser, F. H. Beck and M. G. Fontana, Ohio State University, Columbus.

Earlier work by other investigators has shown that nitrous acid is involved in the passivation of iron in concentrated nitric acid solutions. This paper describes the effect of NO, HNO_2

(Continued on Page 120)

BIOGRAPHIES

FRANKLIN H. BECK—Associate professor and assistant director of the Corrosion Research Laboratory at Ohio State University. He has a BS in metallurgical engineering, Pennsylvania State University (1943) and a PhD from Ohio State University (1949). He is a member of the NACE Editorial Review Subcommittee, has been active on technical programs at NACE meetings and has authored and co-authored numerous papers on corrosion.

W. W. BINGER—Assistant Chief of the Chemical Metallurgy Division, Alcoa Research Laboratories, Aluminum Company of America. He joined Alcoa in 1943 and has held his present position since 1953. His principal work has been in applications of aluminum alloys in the chemical industry. He has a BS in chemical engineering, University of Wisconsin (1943) and is author and co-author of numerous papers on corrosion.

C. F. CHENG—An engineer in the Large Steam Turbine-Generator Department, General Electric Company, Schenectady, New York. Previously he spent nine years with The International Nickel Company, where he was in charge of its technical office in China and reassigned in 1950 to its Research Laboratory. His other associations include U. S. Steel Export Co., Republic Steel Corporation and Wah Chang Refining and Smelting Co. He received a degree in chemical engineering from Massachusetts Institute of Technology (1940).

HARRY R. COPSON—Dr. Copson, head of the Corrosion Section of the Research Laboratory, The International Nickel Co., Inc., Bayonne, N. J., has been chairman of the Corrosion Division of The Electrochemical Society and general chairman of the society's 1953 New York meeting. In 1949 he was chairman of the AAAS Gordon Research Conference on Corrosion and in 1946 was awarded the Dudley Medal of the ASTM. Active on many corrosion committees, author of many papers he has a BS from University of Massachusetts (1929) and PhD in physical chemistry from Yale (1932). He has been active in corrosion research since 1934.

MARS G. FONTANA—A past-president of NACE, he is professor of metallurgical engineering and research at Ohio State University. He holds several degrees, has received many honors including the NACE Speller Award, and is author and co-author of numerous papers on corrosion processes. He also acts as consultant on corrosion problems for several big industrial firms.

C. P. LARRABEE—Since 1935 in charge of corrosion work on all products of United States Steel Corp. except tinplate, he spent 10 years in the chemistry division of National Bureau of Standards following his graduation and before joining U. S. Steel's staff. He is retiring chairman of NACE's Technical Practices Committee after two years' service, has been a director of the association, active in the technical work of NACE otherwise and has found time to write

(Continued on Page 120)

INCO TRADE MARK Monel to the rescue

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BIOGRAPHIES

(Continued From Page 116)

F. H. MEYER—Associate Research Physicist, Continental Oil Co., Ponca City, Okla. A member of the American Physical Society, the American Crystallographic Association and the American Chemical Society, he has a science degree from the College of the City of New York and on MS in physics from Polytechnic Institute of Brooklyn.

G. A. NELSON—Staff metallurgist for Shell Development Co., Emeryville, Cal., he formerly was metallurgist with Shell's Pittsburgh, Cal. ammonia plant. He worked for National Lead Company and American Smelting & Refining Company before joining Shell. He attended Armour Institute, Lewis Institute and MIT. Among other activities he is a member of ASTM Committee A-1, secretary of the petroleum panel of the joint ASME-ASTM Committee on the Effect of Temperature on the Properties of Metals; a member of ASM in which he is chairman of its committee on Stainless Steel in Chemical Uses.

WILLIAM G. RENSHAW—Mr. Renshaw received a BS in chemical engineering from Pennsylvania State University and has been with the Allegheny Ludlum Steel Corp. for the past 15 years. At present, he is Supervising Chemical Engineer of the Corrosion Section of the Research Laboratories of that Company. He is an active member of NACE having held various offices in the Pittsburgh Section.

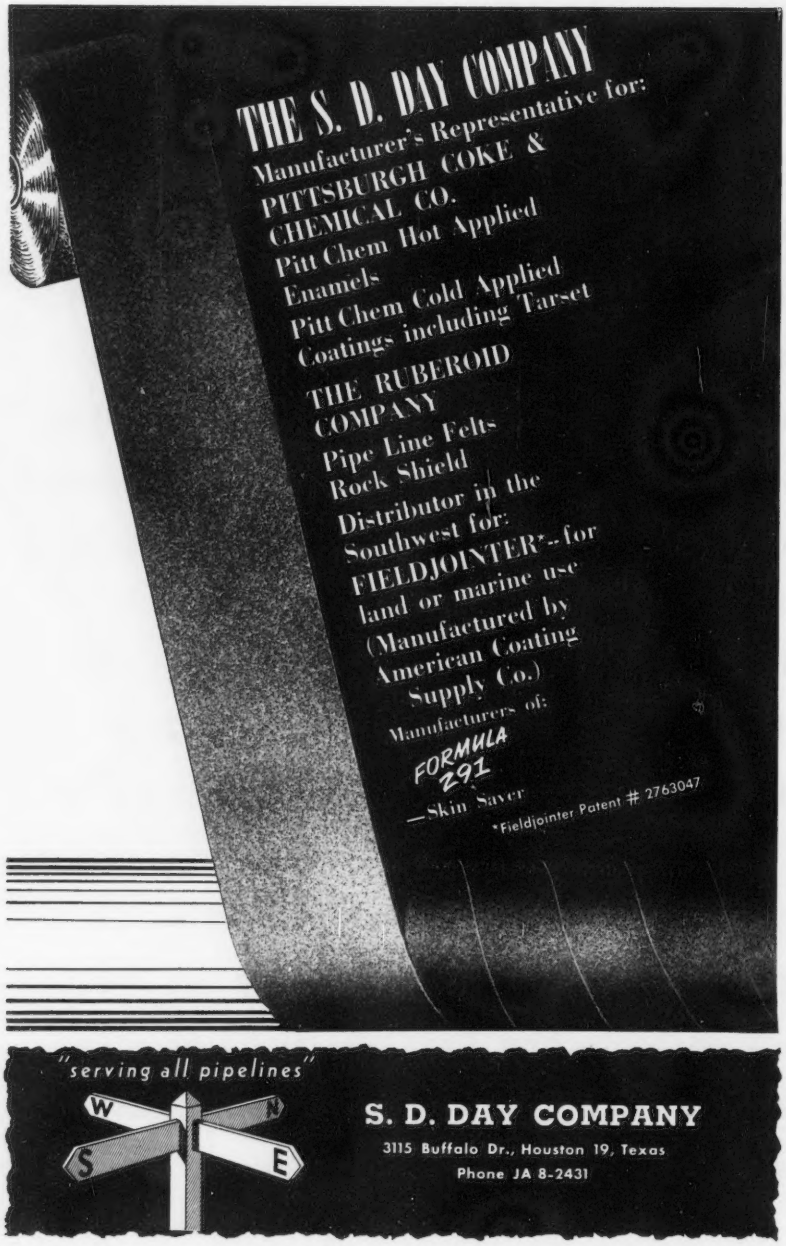
O. L. RIGGS, JR.—As a member of Continental Oil Company's Research Department since February 1952, he has worked on corrosion chemistry and related problems. He has a BS in chemistry from Eastern Nazarene College, Boston, Mass. and was a teacher in Ohio public schools for two years. He is a member of NACE.

G. L. SNAIR—Development engineer specializing in corrosion with Allegheny Ludlum Steel Corporation. For 17 years he was employed in the Corrosion Department, Research Laboratory of his company. He has a BS in chemistry from Thiel College and a graduate course in chemistry and metallurgy at Carnegie Institute of Technology.

J. D. SUDBURY—Research Group Leader, Development and Research Department, Continental Oil Co., he holds a PhD in physical chemistry, University of Texas, 1949. He is a member of NACE among other engineering organizations and for the past eight years he has been active in oil well corrosion research. He is active in NACE and author of many papers on corrosion control.

E. S. TROSCINSKI—Research engineer in Corrosion Section, Materials Division, Engineering Research Department, Standard Oil Company (Indiana), he received a BS in chemical engineering from University of Illinois (1951). He formerly was with U. S. Rubber Company and Corn Products Refining Co.

E. A. WRIGHT—Metallurgist for Wolverine Tube Division of Calumet & Hecla Inc., Detroit, he has been engaged in developing tube fabrication techniques for new alloys and in determining causes of tubing failures in service. He has a BS in mechanical engineering from Alabama Polytechnic Institute. He presently is active in ASME.



Chemical Industry—

(Continued From Page 118)

and HNO_3 on the corrosion of active Type 304 stainless steel by 10 percent H_2SO_4.

Specimens of Type 304 stainless steel strip 0.005-inch thick, activated by abrading on 240-grit emery cloth and exposed to 10 percent H_2SO_4 solutions were passivated by bubbling nitric oxide through the solution. Bubbling oxygen through the solution did not passivate these abraded specimens. Abraded specimens exposed to an atmosphere of NO before immersion in NO-free H_2SO_4 remained active. Spot tests of 10 percent H_2SO_4 treated with NO revealed the presence of nitrite and nitrate ions in the solution. The addition of one part of 10 percent HNO_3 to 60 parts of 10 percent H_2SO_4 was found to produce passivity of abraded stainless steel specimens exposed to the solution.

On the Mechanism of Stress Corrosion of Austenitic Stainless Steels in Hot Aqueous Chloride Solutions by K. W. Leu and J. M. Holle, Koninkje/Shell Laboratorium, Amsterdam.

An investigation of the mechanism of transcrystalline stress corrosion of austenitic stainless steels (18-8 and 25-20) in hot aqueous chloride solutions shows this phenomenon is a process alternating between corrosion and mechanical cracking. Sharp-edged pits formed by corrosive attack initiate and propagate mechanical cracking, which is of brittle nature. Pits act as stress raisers to produce notch brittleness in materials involved.

At low stresses only long pits at slip bands initiate cracking while at high stresses small pits at slip bands or grain boundaries may cause it. The investigation proves also initial corrosive attack depends principally on the physical and chemical behavior of the passivating film already on the steel or formed during exposure to the environment, and only to a minor degree on metal structure.

If the type of initial corrosion is changed by comparatively small alternations in composition of the corrosive medium stress corrosion either is prevented or accelerated. Tests illustrating this are discussed.

BIOGRAPHIES

(Continued From Page 118)

numerous articles on corrosion control. He also is a member of numerous other scientific and technical organizations as well as a sought after lecturer on corrosion.

LLOYD F. LOCKWOOD—Research and Development Engineer in the Wrought Alloy Section, Magnesium Research Laboratory, The Dow Chemical Co., Midland, Mich. He has an MS in metallurgical engineering from Ohio State University (1955) and a BS in metallurgical engineering from Michigan College of Mining and Technology, Houghton (1954). He joined Dow in June 1955.

W. L. MATHAY—Technologist, Applied Research Laboratory, United States Steel Corporation, Monroeville, Pa. He received a BS degree in chemistry from Thiel College in 1947 and completed requirements for an MS degree in chemistry at Carnegie Institute of Technology. He had several years of experience in water treatment before joining the U. S. Steel Corporation in 1954. As Section Leader of the Chemical and Process Corrosion group he is now engaged in the mitigation of corrosion problems, particularly in the coal chemical field. Mr. Mathay is a member of NACE.

ROBERT R. PIERCE—Manager of the Corrosion Engineering Products Dept. of Pennsylvania Salt Manufacturing Co., he is a director of NACE, formerly was chairman of Philadelphia Section and is active in the association's technical committee work. He joined Pennsylvania Salt in 1941 and was promoted to his present position in 1951. He is author and co-author of numerous papers on corrosion control.

An alphabetical subject and author index of the CORROSION Technical Section is compiled and published in December.

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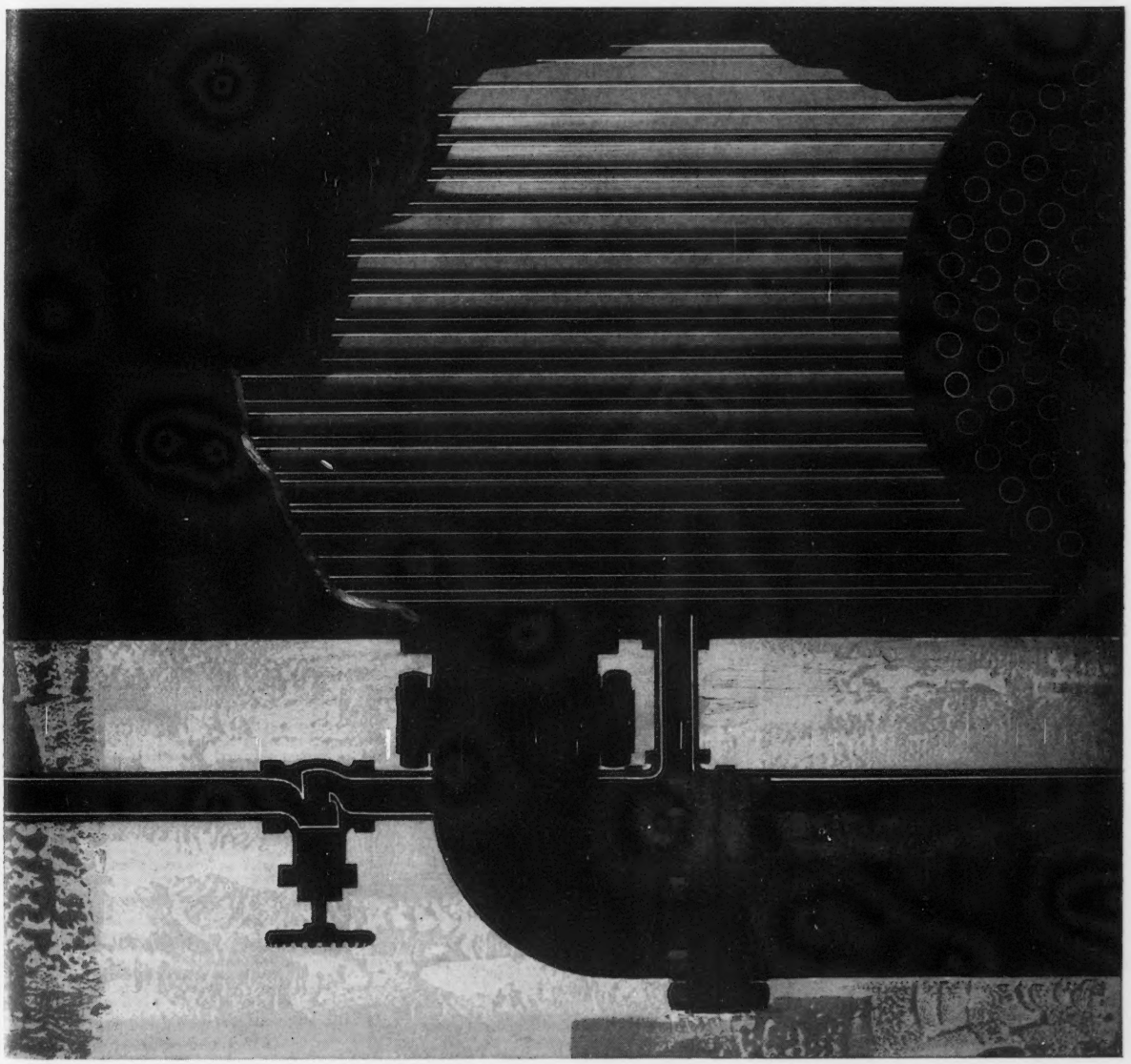

Miller

Nelson

Preiser

Ringer

Sudrabin

Ticker

Criteria, Galvanic and Inert Anodes to Be Discussed at Cathodic Protection Session

Five papers to be presented during the Cathodic Protection Symposium, 2 to 4:30 pm March 13 at St. Louis cover criteria of protection, simulated galvanic anode arrays, external corrosion of a pipe line, current distribution studies and an investigation of graphite and high silicon anodes.

Usual wide interest in cathodic protection will be enhanced by the diversity of subject matter of the scheduled papers.

Some Observations of Cathodic Protection Criteria by L. P. Sudrabin, Electro Rust-Proofing Corp. and F. W. Ringer, Consultant, Narberth, Pa.

Tests made on a 240-foot section of 6-inch bare pipe and a copper-iron ball corrosion system buried in 20-30,000 ohm-cm soil to show that: 1) Discharge of current continues from edges of zinc plates connected to the pipeline when the net closure circuit current flow is made zero. 2) Short lines of corrosion current flow from anodic areas even though net flow to anode area on pipe is shown to be zero. 3) As pipe-to-reference electrode distance increases, measured potential must be more negative if short line corrosion is to be stopped. 4) In a mixed system the "apparent break" in the potential-log current density relation is not reliable as an indication of protective current requirements.

Current-Voltage Relationship of Galvanic Anode Arrays in Cathodic Protection by L. J. Waldron and M. H. Peterson, Naval Research Laboratory, Washington, D. C.

An array of steel anodes was established in water with a resistance of 34-38 ohm-cm with an average depth of 20 feet in a system including an unpolarizable long sea wall. Tests of the impressed current at levels characteristic of galvanic anodes in various combinations showed: 1) Mutual interference was observed in all arrays. 2) Moderate separation is inefficient in increasing current output.

A general equation is presented which may be used to calculate with some error current output of arrays of sizes or arrangements different from the test series.

Control of External Corrosion on the Trans-Arabian Pipeline by F. H. Maasry, Trans-Arabian Pipe Line Co., New York.

Data are given on the cathodic protection system of the line including geophysical conditions of the route, design, unattended engine-generator stations, control on short buried sections, control at pumping stations and cathodic protection of submarine lines.

A Study of Current Distribution in Cathodic Protection by E. E. Nelson, Naval Research Laboratory, Washington.

An analysis of the effects of solution resistance and cathodic polarization on current distribution in cathodic protection of metals is presented. Formulae are modified to calculate the relative importance of resistance and polarization in influencing current distribution.

An experimental method of determining current density on various parts of a large cathode is described.

Calculations are presented showing effect of paint films on current distribution and advantages of good paint coatings in cathodic protection.

Electrical Deterioration of Graphite and High-Silicon Cast Iron Anodes in Sodium Chloride Electrolytes by W. L. Miller, A. Ticker and S. Tudor, Material Laboratory, New York Naval Shipyard, Brooklyn and H. S. Preiser, Naval Research Laboratory, Washington, D. C.

Laboratory test apparatus and procedures were developed for correlating data on the electrochemical deterioration rates of various graphite and high-silicon cast-iron anodes vs current drain in NaCl electrolytes of 50, 1000 and 5000 ohm-centimeter specific resistivities. Effect of impregnation on graphite anode performance is indicated.

Improved graphite durability in lower specific resistivity electrolyte is indicated. Lower deterioration rates for cast iron than those achieved with graphite were observed in high resistivity electrolytes. In low resistivity solutions attack on high-silicon cast iron by generated chlorine should be considered.

•

CORROSION is indexed annually in December.

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Tudor

BIOGRAPHIES

WALTER L. MILLER—Head of the Metal Chemistry Section, Material Laboratory, New York Naval Shipyard, Brooklyn, he entered government service in 1930 and has been occupied in problems associated with the chemistry of metals since 1934. He has a BA in chemistry from Columbia (1929) and has had additional courses at Pratt Institute and Brooklyn Polytechnic Inst.tute. Among other technical organizations he is a member of NACE.

E. E. NELSON—Recently working on petroleum corrosion problems at the Socony Technical Service Laboratory, he is on the consultant staff of the Corrosion Metallurgy Division, Naval Research Laboratory, Washington, D. C. After service in the Navy, he joined the Naval Research Laboratory in 1946 in the Electrochemistry Branch and changed to the Corrosion Branch in 1952 where he worked on problems relating to cathodic protection of ships. He has a BS in chemical engineering, University of Cincinnati (1941).

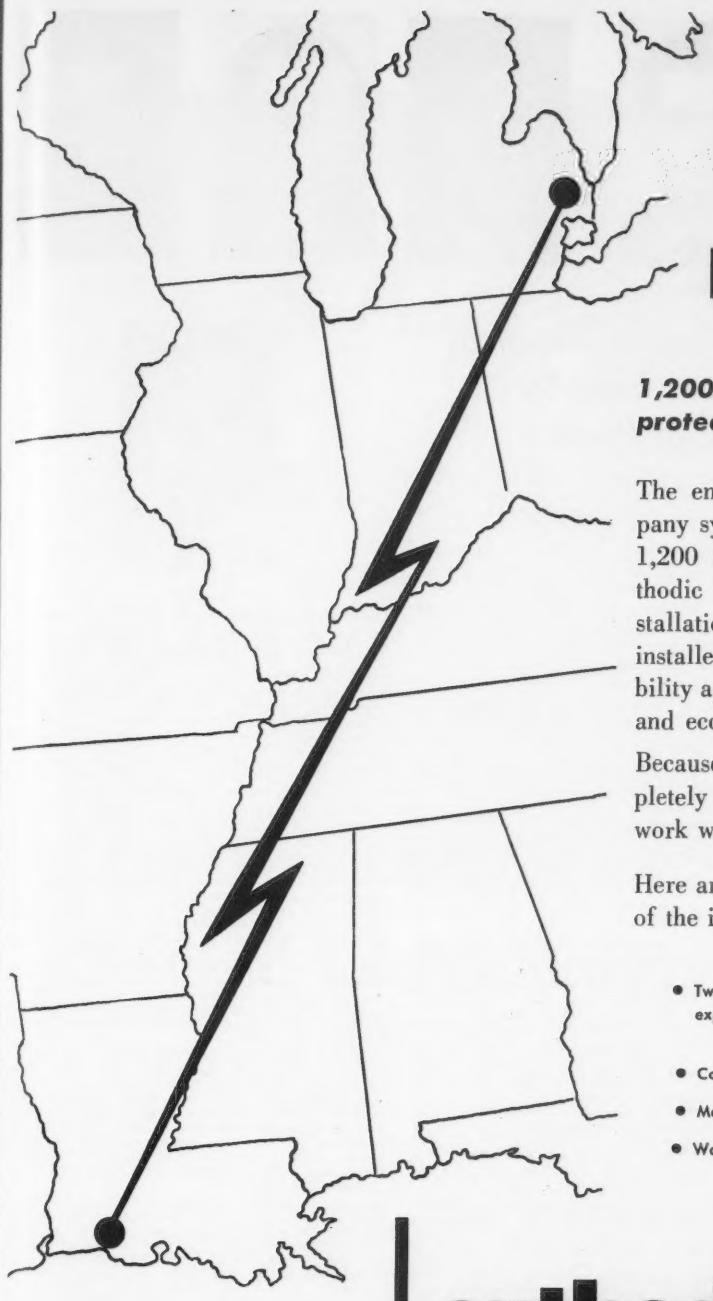
HERMAN S. PREISER—In the Bureau of Ships, Washington, D. C., where he is corrosion engineer in charge of cathodic protection for the Research and Development Division he is actively working on corrosion problems of the fleet. He is a graduate of the New York State Maritime College and Webb Institute of Naval Architecture and a licensed professional engineer in the District of Columbia and in Virginia. He is a member of NACE, the Society of Naval Architects and Marine Engineers and The Electrochemical Society.

F. W. RINGER—A consulting engineer, he has done corrosion control work with Standard Oil Company of New Jersey, Oklahoma Pipe Line Co., Interstate Oil Pipe Line Co., and Texas Eastern Transmission Corp. He has a BS in electrical engineering from University of Oklahoma and among others is a member of AIEE, NACE, ECS, AGA and is active in NACE and the American Gas Association in technical committee work.

L. P. SUDRABIN—Consultant to Electro Rust-Proofing Corp., Belleville, N. J., he is chairman of and active on several technical committees of NACE involving cathodic protection. Among others he is a member of AIChE, ECS and is a registered professional engineer in New Jersey and other states. He has a BS in chemical engineering, Northeastern University, Boston (1936) and before joining his present firm worked for the Dorr Company, Dayton Power and Light Co. and Boston Edison Company. He is author of many papers on cathodic protection and in demand as a technical speaker.

ARTHUR TICKER—He is a chemist in the Material Laboratory, New York Naval Shipyard, Brooklyn. For the past three years has been occupied with research and development of cathodic protection systems as applied to the hulls of naval vessels. He previously worked in the fields of metal chemistry and protective coatings. He has a BS in chemistry, Long Island University (1941) and is a member of NACE and ACS.

(Continued on Page 124)



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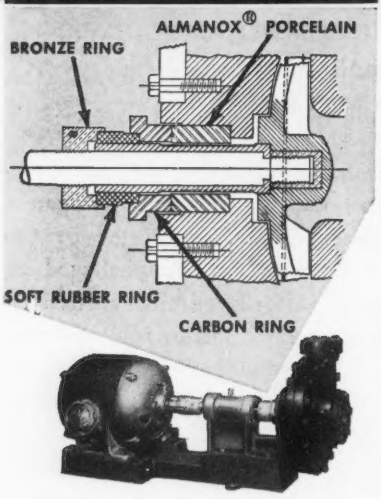

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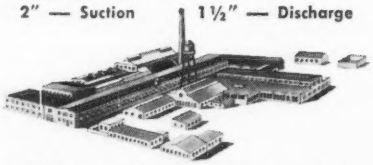

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Plastics In Chemical Process Industry Topic of Papers

Papers covering use of plastic pipe, ducts and vessels and one on engineering properties of rigid polyvinylchloride will be given during the Plastics Symposium at St. Louis. The symposium will be held from 9 to 11:30 am March 14.

All papers contain basic engineering data useful in design work and are intended to survey the present position of plastics in the areas discussed.

Abstracts follow:

Present Status and Potential Use of Plastic Pipe in the Chemical Process Industry by Raymond B. Seymour, Corrosion Resistant Products, Inc., Newhall, Cal.

Advantages and disadvantages of using plastic pipe and the importance of using realistic data on chemical and physical properties are emphasized. Examples are given to show that lack of ingenuity and engineering knowledge has hampered full use of plastic pipe.

Successful use of plastic pipe as inserts in deteriorated metal is suggested as a catalyst for creative thinking by engineers. Examples are given to show that sufficient knowledge of properties is available now to permit using plastics to solve many corrosion problems.

Engineering Properties of Rigid Polyvinylchloride by Kenneth A. Phillips, American Zinc, Lead and Smelting Co., East St. Louis, Ill.; Walter B. Meyer, St. Louis Metallizing Co., St. Louis, Mo. and Otto H. Fenner, Monsanto Chemical Co., St. Louis, Mo.

After a history, the nature of polyvinylchloride variations in the types and percentages of plasticizers are related to workability during fabrication and to engineering properties. Variations in the latter related to temperature are shown in tables and graphs.

Shop and field fabrication methods are discussed with emphasis on relation of methods to strength and stability. Many examples of successful use are given and a few warnings on the need to train properly operating and maintenance personnel are voiced.

Present Status of Plastic Vessels in the Chemical Process Industry by John W. Carrow III, Haveg Industries, Inc., Wilmington, Del.

Plastic tanks, columns and process vessels are now an important and integral part of corrosion resistant equipment used in chemical and allied industries. Single component plastic vessels offer a number of outstanding advantages not gained by multi-component construction.

Self-supporting vessels of a single material have uniform corrosion resistance through their mass. Although raw material costs are high ever-improving methods justify the use of plastic vessels in an expanding number of cases.

Present Status of Plastic Ducts and Stacks in the Chemical Process Industry by J. L. Huscher, Kaye-Tex Mfg. Co., Inc.

A number of plastics are now finding extensive and constantly increasing use as materials of construction for corrosion-resistant exhaust hoods, ducts and stacks in the chemical and allied process industries. A short review of this development, the materials and the increasing acceptance of such structures and materials in this country is given.

A number of case histories are reviewed and analyzed with regards to their initial cost, comparison with other materials of construction, their performance and maintenance costs. Based on the experiences gained in the past few years, design considerations, material limitations and new possible uses are discussed to assure better application and utilization of plastic exhaust ducts and stacks.

Seymour

BIOGRAPHIES

JOHN W. CARROW III—General sales manager and advertising manager of Haveg Industries, he has a BS in mechanical engineering from University of Delaware and did graduate study there in chemistry and economics. He worked for Atlas Powder Company before being employed by Haveg in 1947. He was made general sales manager in February 1956 and advertising manager in October, 1956.

OTTO H. FENNER—Mr. Fenner currently is engaged in operations research at the John F. Queeny Plant of Monsanto Chemical Company in St. Louis. Since 1934 when he joined Monsanto he has worked as production supervisor, area supervisor, project engineer, supervising engineer and corrosion engineer. Included in his NACE activities are organization of the Greater St. Louis Section in 1948, chairman of the St. Louis Section, and chairmanship of T-5D-7 on Engineering Design of Plastic Materials of Construction for the Chemical Industry. He also is general chairman of the 1957 NACE Conference and Exhibition, a member of NACE T-6A Committee on Organic Coatings, president of St. Louis Professional Chapter of Alpha Chi Sigma and a member of ACS. He has an AB in organic chemistry from Washington University, St. Louis.

JOSEPH L. HUSCHER—Now with Kaye-Tex Manufacturing Co., Yardville, N. J., has spent more than 12 years in various activities connected with corrosion control. This experience, which included work on thermoplastic materials, welding electrodes and process equipmeat, was gained first with American Agile Co. He joined his present employer in 1953. He has a BS in chemistry from University of Caen, France and a BS in chemical engineering from Fenn College, Cleveland.

WALTER B. MEYER—President of St. Louis Metallizing Co., he has been active in NACE for many years in technical committee work and in administrative capacities. He has had long experience in all phases of metallizing and is a member of AWS, Society of Plastics Engineers and other engineering organizations.

RAYMOND B. SEYMOUR—President of Loven Chemical of California and Corrosion Resistant Products, Inc., Newhall, Cal., he has had long experience in the design of equipment with plastics and the application of plastic materials to engineering uses. His experience includes work with Goodyear Tire and Rubber Company, Monsanto Chemical Company, Johnson and Johnson and others. He is author of numerous papers and books on plastics, holds over 50 patents and is well known as a speaker on plastics topics.

BIOGRAPHIES

(Continued From Page 122)

SIDNEY TUDOR—He is supervisory chemist (physical) in charge of the Electrochemistry Unit at the Material Laboratory, New York Naval Shipyard, Brooklyn. His experience includes research in cathodic protection, electrolytic derusting, polarography and electrochemical surface reactions. He has a BA from Brooklyn College and an MS in chemistry from New York University. He is a member of NACE among other organizations.

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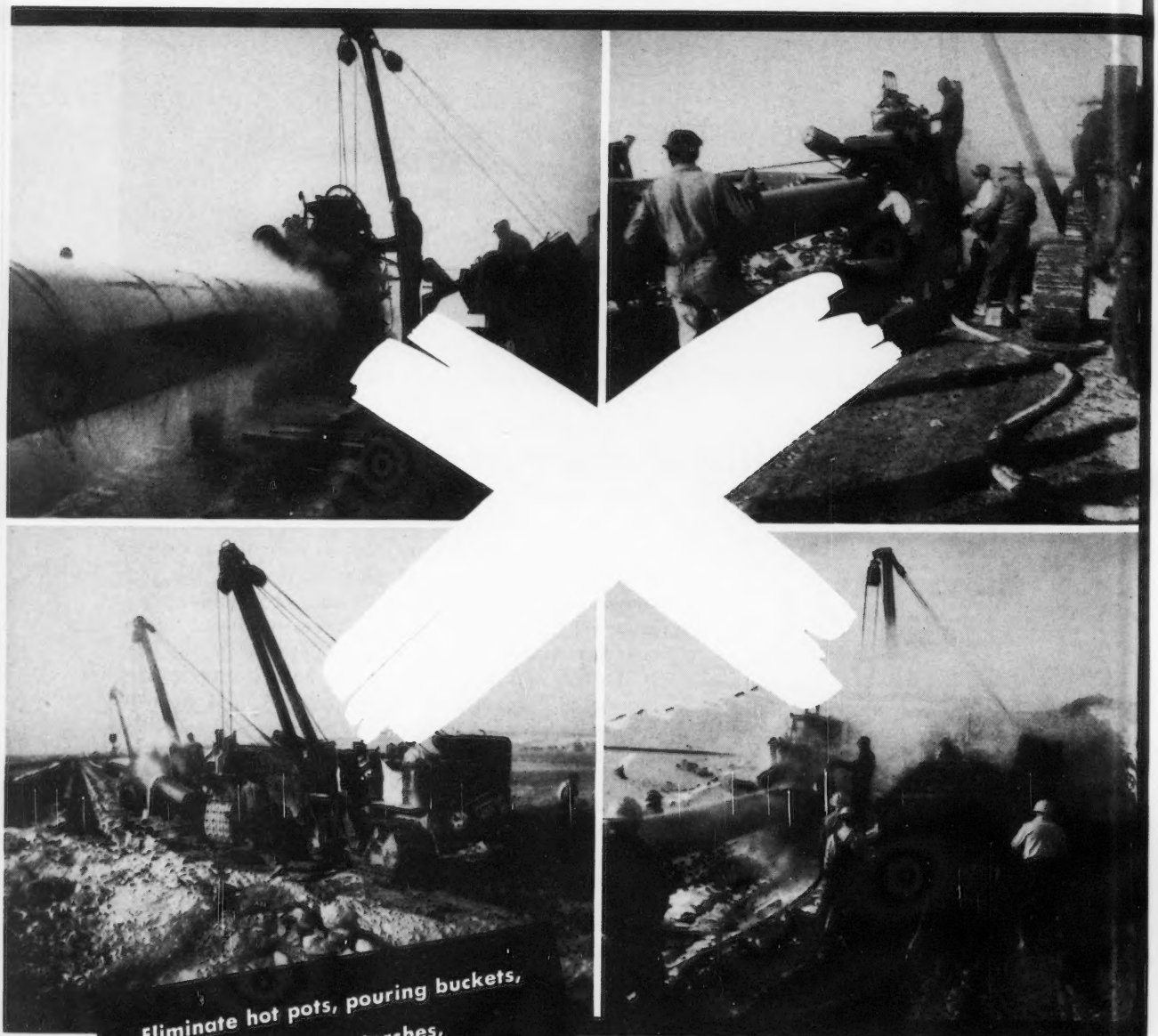

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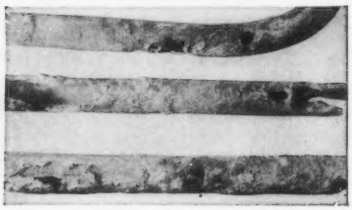

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Residual Oil Ash, Molybdenum and Cermets Are Topics

Two papers dealing with corrosion associated with fuel oil ash, one on molybdenum oxidation and one on the effect of liquid metals on cermets and ceramics will be given during the High Temperature Symposium at St. Louis. The symposium will be held from 9 to 11:30 am March 14.

A Thermochemical Study of Some Additives to Reduce Residual Fuel Ash Corrosion by W. E. Young and A. E. Hershey, Westinghouse Research Laboratory, East Pittsburgh, Pa.

A theoretical study is made of mixtures of vanadium pentoxide and sodium sulfate with various oxides and sulfates. Thermal stabilities of the sulfates were investigation with the conclusion that oxides of calcium, magnesium and aluminum should be effective in controlling "catastrophic" attack on refractory alloys if they could be kept in oxide form. However, it was shown that the sulfate would, in general, be the stable form, particularly at temperatures in gas turbines. Such sulfates are not effective additives and may, in fact, be deposit forming.

Additive with the most promise was found to be an aluminum compound, whose sulfate, even if initially formed, should revert almost entirely to oxide at 800 C at one atmosphere pressure and 920 C at five atmospheres. Some conclusions were confirmed in full scale tests on turbines but more testing is needed for full verification. More extensive and accurate thermochemical data would help to validate calculated results.

Oxidation of Molybdenum by J. F. Mosher, U. S. Air Force, Dayton; E. S. Jones, General Electric Co., Cincinnati; Rudolph Speiser and J. W. Spretnak, Ohio State University, Columbus.

Depending on temperature and time, the scale formed on molybdenum consists of either two or three oxide layers. The outermost layer is the volatile MoO_3. The inner layers of oxide have a composition very close to MoO_2 but do not exhibit an X-ray pattern corresponding to MoO_2.

The rate of evaporation of MoO_3 and the mechanism of molybdenum oxidation were determined. It was found that after an initial parabolic dependence of weight change upon time the rate of oxidation became linear. This is due to the fact that the outer MoO_3 layer is non-protective so that the rate of oxidation of the suboxide to the trioxide at the suboxide-trioxide interface is equal to the rate of diffusion of oxygen through the suboxide film to the metal-suboxide interface. It was also found that the presence of liquid MoO_3 increased the rate of oxidation of molybdenum.

Cook

Hershey

Young

Corrosion Resistance of Various Ceramics and Cermets in Liquid Metals by W. H. Cook, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Procedures for corrosion testing of ceramics and cermets in liquid metals are discussed briefly. Results of these tests on various ceramics and cermets are summarized. These include borides, carbides, nitrides, oxides and silicides for the ceramics plus a brief account on graphites similarly tested. The major part of the report on cermets is on titanium carbide and tungsten carbide cermets. Some present and future practical utilizations of corrosion resistant ceramics and cermets are given.

Present Status of Oil Ash Corrosion Problems by R. T. Foley, General Electric Co., Schenectady, N. Y.

Several cases of fuel oil ash failures in the field are reviewed to point out characteristics of the problem. Solutions to the problems of corrosion by residual fuel oil ash are discussed under the following headings: 1. Inhibitors. 2. Changing alloy composition. 3. Lowering operating temperature. 4. Altering composition of the oil.

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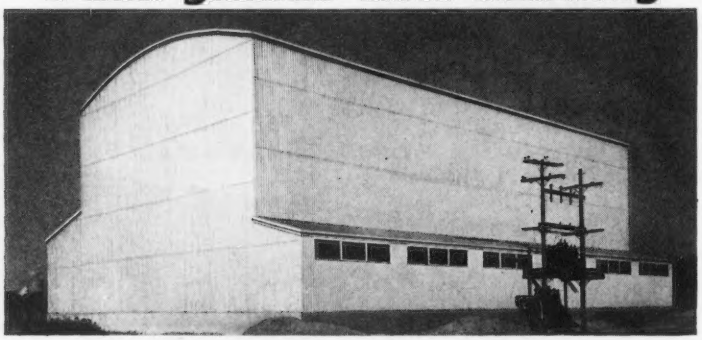

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BIOGRAPHIES

W. H. COOK—Since 1954 Mr. Cook, as a member of the General Corrosion Group, Metallurgy Division, Oak Ridge National Laboratory has been concerned with investigation of high temperature compatibility of ceramics and cermets with each other, metals or fluid media and work related to the use of ceramics and cermets in reactors. He has BS and MS degrees in ceramic engineering from University of Texas (1949, 51) and from 1951 to 1954 was employed by the U. S. Bureau of Mines, Region VII at Norris, Tenn., where he tested raw materials and refractories.

A. E. HERSHEY—Advisory engineer, Westinghouse Research Laboratories, he is engaged in combustion and thermodynamic research and development for industrial gas turbines. From 1926 to 1942 he was with the Engineering Experiment Station, University of Illinois. He has a BS in mechanical engineering, Carnegie Institute of Technology (1922); MS (1926) and PhD (1941) mechanical engineering, University of Illinois.

W. E. YOUNG—Research Engineer, Westinghouse Research Laboratories, he is engaged in combustion and thermodynamic research for industrial gas turbines. He has a BS, mechanical engineering, Uni-

(Continued on Page 129)

Power Plant and Cable Corrosion Problems Reviewed

Corrosion problems in power plants and on power cables are covered in papers to be given at St. Louis during the Power and Communication Symposium. It will be held from 2 to 4:40 pm March 14. Four papers in the symposium are abstracted below:

An Artificial Insulating Joint for Stray Current Mitigative Measurements by G. H. Cantwell, Indiana Bell Telephone Co., Indianapolis.
In making electrical measurements pertinent to determining stray current mitigative measures, it often is desirable to know the effect of a proposed insulating joint at a predetermined location. By applying a direct current source between the structure and the earth in the manner described in the paper, simulation of an insulating joint is achieved. Because the method is entirely electrical, placing of temporary insulating joints for test purposes is eliminated. This method can be applied to any structure carrying stray earth DC.

In addition to simulating an insulating joint, the associated current and potential measurements are used to determine the resistance to earth of the structure on each side of the point of application; the potential to earth that would exist on each side of a permanent insulating joint; the potential across the permanent insulating joint and also provide data for determining the resistance and current carrying capacity for a bridging resistor.

Effect of Pressure on the Corrosion of Feedwater Heater Tubes by Evaporator Vapor Containing Carbon Dioxide and Oxygen by J. M. Decker, Detroit Edison Co., Detroit, Mich.
Water from Detroit River contains approximately 80 ppm of bicarbonate hardness and from 8 to 14 ppm of dissolved oxygen. When this water without treatment is fed to evaporators, the vapor produced contains about 35 ppm of carbon dioxide and an amount of oxygen approximately equal to the amount in the feedwater. Although this vapor contains relatively high concentrations of these corrosive gases, it can be condensed in feedwater heaters that operate below atmospheric pressure with little or no damage to the heaters. If, however, the vapor is condensed in feedwater heaters that operate above atmospheric pressure, the heater tubes are rapidly damaged by corrosion. Corrosion in this case can be minimized by pretreating the feedwater to remove bicarbonate and dissolved oxygen.

Electrical Measurements and Their Interpretation in Underground Cable Corrosion Problems by K. G. Compton, Bell Telephone Laboratories, Murray Hill, N. J.
Methods of making duct surveys, surface potential gradient surveys, measurements of cable-to-reference electrode potentials, sheath currents and earth resistivity are described. Examples are given of various types of measurement and their interpretation. It is pointed out that a single measurement of the potential between a cable sheath and a reference electrode in contact with nearby earth may not reveal the existence of a corrosive condition. Emphasis is given to the difference in polarity between self-produced corrosion cells and those resulting from external influences such as stray current or contact with a more noble metal. The importance of employing a variety of measurements in any particular study is shown by several of the examples. References are given to techniques employed by other workers in making underground corrosion tests.

Corrosion Experience With Pipe-Type Cables in Ontario by R. C. Jacobsen, Hydro-Electric Power Commission of Ontario, Toronto.
When the first pipe-type cables were installed by Ontario Hydro in 1951 there were no staff dealing regularly with underground corrosion. By the time the conditions had been studied and cathodic protection devised and applied leaks had developed. Profiting from experience, more recent installations have had protection from shortly after burial of the pipe. Recently polarization cells have been developed to replace some of the lead-acid batteries initially installed.

BIOGRAPHIES

(Continued From Page 128)

versity of Vermont (1941), PhD (1956) in mechanical engineering, University of Pittsburgh, where he is a lecturer. He is a member of ASME and NACE.

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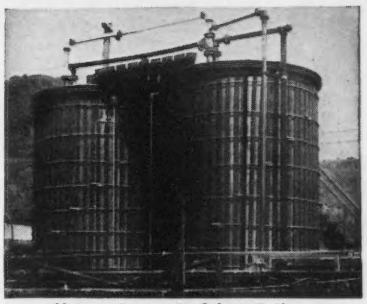
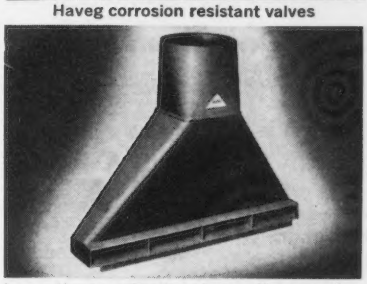
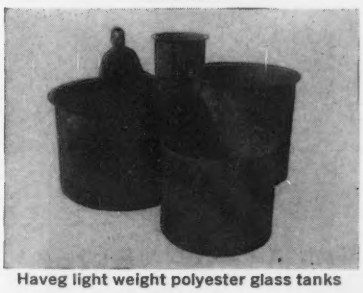


Haveg storage tank installation

Haveg corrosion resistant valves



Large Haveg polyester glass self-supporting fume hood



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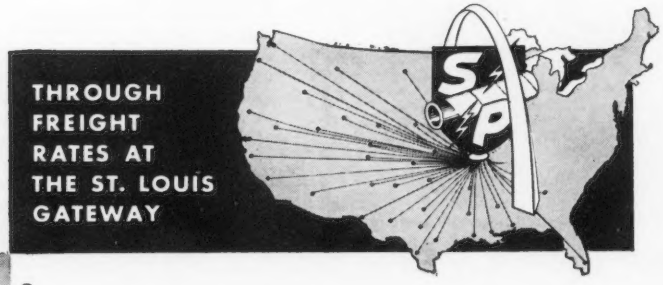

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High Purity Water Symposium to Have 5 Papers at St. Louis

Five papers are scheduled to be given during the High Purity Water Symposium March 14 from 2 to 4:30 pm. The session will be held at Kiel Auditorium, St. Louis during the NACE 13th Annual Conference and Exhibition.

Data on high pressure and high purity water systems in atomic reactors, high pressure boilers and materials used in these systems will be discussed.

Measurement of Corrosion Products in High Temperature High Pressure Water Systems by A. A. Sugalski and S. L. Williams, General Electric Co., Knolls Atomic Power Laboratory, Schenectady, N. Y.

The concentration of corrosion products and other impurities which produce undesirable radionuclides must be maintained at extremely low values in the primary coolant systems of nuclear power plants to keep the resulting radioactive dose rate below certain maximum values. In the development of purification systems for maintenance of these low concentrations it is necessary to measure the concentration of the various impurities and their solubility as they exist at the primary coolant temperature. This paper describes the development of a high efficiency filter used for this purpose and gives data obtained from both radioactive and non-radioactive water systems.

Corrosion of Aluminum-Nickel Type Alloys in High Temperature Aqueous Service by F. H. Krenz, Atomic Energy of Canada, Ltd., Chalk River Project.

Corrosion of aluminum alloys in high purity water has been studied at temperatures in the range of 500-600 F with special reference to the effect of minor alloying constituents on the character and composition of the corrosion film.

Corrosion of Aluminum Jacketed Fuel Elements in Reactor Cooling Water by J. M. Atwood and R. J. Lobsinger, General Electric Co., HAPO, Richland, Wash.

In-pile corrosion rates of fuel elements clad in M-329 and M-388 aluminum have been determined in de-mineralized water at temperatures up to 200 C. A correlation between corrosion rates and the effective aluminum surface temperature is presented. The effect of pH is discussed and results of supporting out-of-pile tests are described.

Storage of High Purity Water by Richard R. Dlesk, Commonwealth Edison Co., Chicago, Ill.

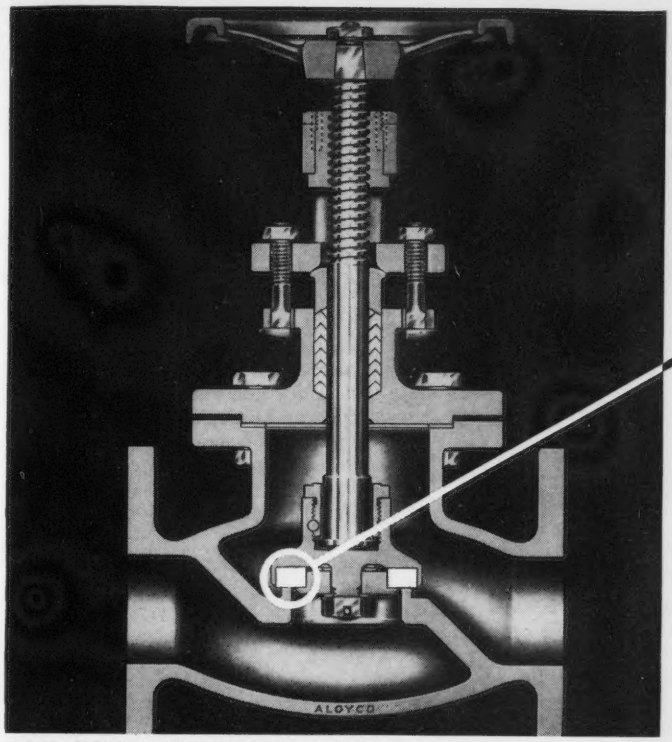
Electric utilities have developed rapidly the need for water of higher and higher purity. As the purity of the water has increased, its storing has become increasingly difficult. In order to mitigate this problem, investigations and appraisals of new protective measures for existing steel tanks were made and some were applied to installations. Aluminum, as a construction material for storage facilities, was evaluated in laboratory and field tests. These tests resulted in the construction of four 44,000-gallon aluminum storage tanks.

Water Conditions for High Pressure Boilers by D. E. Voyles and E. C. Fiss, Duke Power Co., Charlotte, N. C.

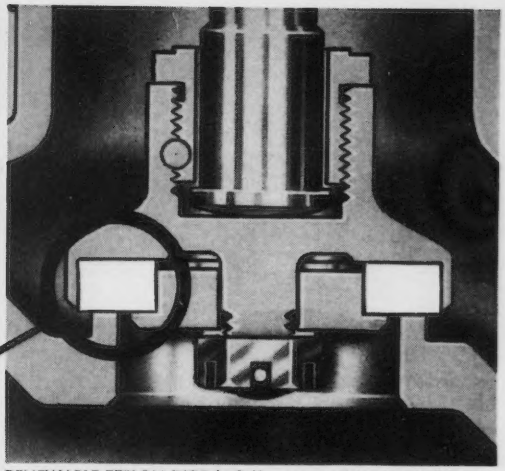
Components of a high pressure boiler system which are in contact with high purity water are described. Materials of construction and operating pressures and temperatures are given for condensers, feedwater heaters and boiler components. Demineralized and evaporated make-up are referred to along with data on the chemical nature of the water. Analyses of water and steam samples from points in the boiler water cycle show iron and copper contents and other indications of the purity and corrosiveness of the water. The part played by chemical treatment, boiler blowdown, removal of dissolved gases and other operating factors in maintaining the described water conditions are discussed.

EXHIBITION HOURS SET

Hours during which the 13th Annual NACE Exhibition at Kiel Auditorium, St. Louis will be open to visitors are: Tuesday, March 12 through Thursday, March 14—9 am to 5 pm. Friday, March 15—9 am to Noon.



150 LB. ALOYCO GLOBE VALVE features bolted bonnet, and outside screw and yoke construction which keeps stem threads out of contact with corrosive fluids. Two piece gland plates and followers. Sound, heavy section body and bonnet castings. Stainless bolts. Heavy finished stem. Renewable yoke bushing. Flanged or screwed ends.



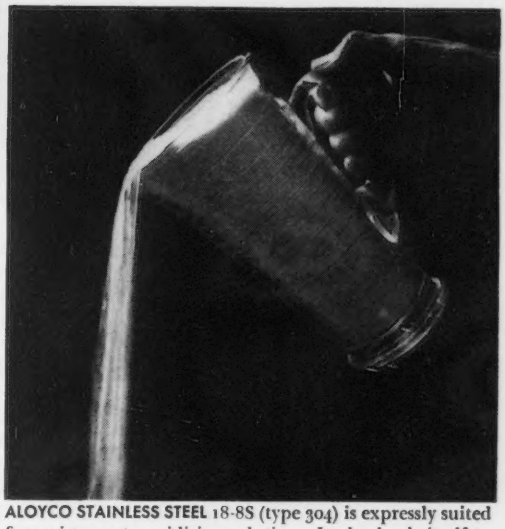
RENEWABLE TEFLON DISC is fully retained in disc holder so that even heavy overloads can't force it out of place. Machined seating surface assures wide full contact with disc and protects against distortion. Teflon V-type chevron packing rings are also used in deep stuffing box.

Tips on selecting valves to combat oxidizing solutions

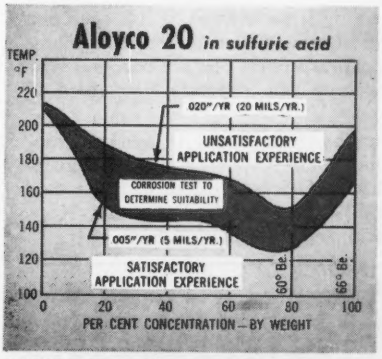
High chromium and chromium-nickel stainless steels are the best alloys for these corrosive applications.

When exposed to oxidizing solutions they form protective films which restrain corrosive attack. Aloyco 18-8S, 18-8S mo and Aloyco 20 are good examples.

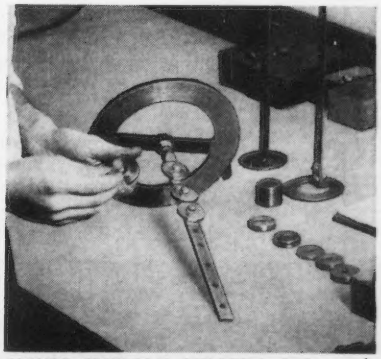
Valves should be constructed so that slight wear or corrosion won't require costly valve replacement. Renewable seats or discs shown above are one answer to this problem. So are deep stuffing boxes and outside screw and yoke construction. And, of course, all valve parts that come in contact with the corrosive fluid should be alloy steels. 6.18



ALOYCO STAINLESS STEEL 18-8S (type 304) is expressly suited for resistance to oxidizing solutions. It also lends itself to innumerable other applications to prevent product contamination or discoloration. In Aloyco 18-8S mo (type 316), molybdenum is added to increase resistance to attack by pitting.

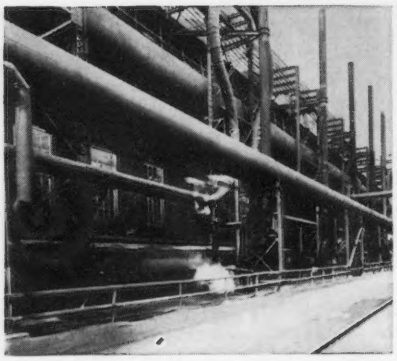


ALOYCO 20 provides a high order of corrosion resistance to a wide range of sulfuric acid concentrations at varied temperatures as indicated by the graph above.

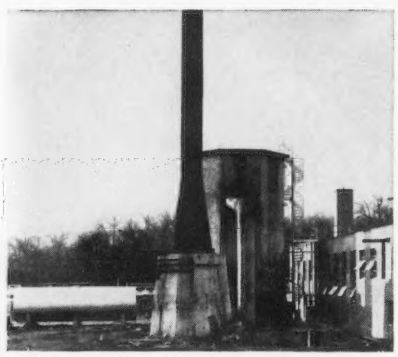


ALOYCO TECHNICAL SERVICE includes engineering counsel, metallurgical assistance and field service. Samples are being prepared for plant line test above.

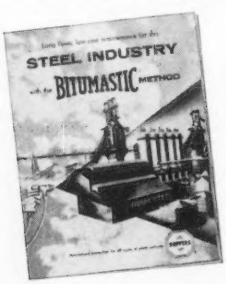
FOR FURTHER INFORMATION on Aloyco corrosion-resistant valves, write to Alloy Steel Products Company, 1304 West Elizabeth Avenue, Linden, New Jersey.



Steel Plant outside piping, structural work and building siding is protected against corrosive attack with Bituplastic® No. 28. This coal-tar base coating material was especially developed to give long-lasting, durable protection to metal and concrete surfaces exposed to weathering and sunlight. Ductile and resistant to "alligatoring," Bituplastic No. 28 gives a film thickness, in one application, of from 3 to 5 times that of conventional paints.



High Temperature Stack is protected against corrosion by a coating of Bitumastic® Hi-Heat Gray, a zinc-base coating designed for high-temperature protection. Intermittent temperatures up to 1000° F. and continuous 800° F. dry heat will not affect this coating material, and it is widely used for protection of boiler breeching, stacks and other hot metal surfaces.



Corrosion Engineers will find this new booklet from Koppers a useful reference in planning corrosion-preventive practices in the steel industry. It outlines the usual recommendations for various surfaces and application techniques to insure long-term protection of plant structures and equipment. Write for your copy: Koppers Company, Inc., Tar Products Division, Dept. 100C, Pittsburgh 19, Pa.

how to CUT CORROSION LOSSES

a report by Koppers Company, Inc.

Number 9 of a series

W. E. Kemp
Manager, Technical Department

One problem in the protective coating of steel structures is that of *interim protection* between fabrication and erection. In some cases this is a relatively short time; in others, as much as two or three years. Here is a typical question put to us recently by an engineering firm purchasing fabricated steel penstocks for shipment and erection overseas. Since penstocks are constantly exposed to water, coal-tar enamel coating is usually applied after erection.

* * *

"On jobs where the sandblasting of surfaces to bright metal prior to priming and coating is mandatory and the time between fabrication and erection is 3 months to 1 year, should we (1) shop-prime only before shipment or, (2) ship uncoated or, (3) sandblast and prime in the shop, then ship and clean (not sandblast) and prime as necessary in the field?"

The inquirer went on to ask what we would recommend if the interim period was *more* than one year or more than *two* years. Obviously, it's difficult to answer questions like this without knowing specific field conditions. However, here are our general recommendations on the protection of steel between fabrication and field enameling.

If specific job conditions specify that sandblasting be done in the field, the best practice would be to ship the steel *uncoated*, provided that it will not be exposed for more than one year to atmospheric corrosion. Actually, the rusting which will occur on the unprotected surfaces will serve to destroy mill scale which should *always* be removed prior to coating. In our experience, shop-priming without sandblasting prior to shipment almost always gives difficulty in the field.

If the steel is to be installed during a period of three months to one year after it leaves the shop and there is a choice as to where the sandblasting will be done, we still recommend the above procedure. Less satisfactory, but the best alternate, would be to sandblast and shop-prime before shipment; then wire brush, prime and enamel in the field.

If the steel will not be enameled or coated for more than two years after fabrication, a detailed examination of the corrosive atmosphere in which the steel will be stored must dictate the coating procedure.

* * *

Another important point in corrosion prevention on fabricated metal is the physical handling necessary for shipment, storage and erection of the structures. If excessive handling is anticipated, it has been our experience that it is more economical and efficient to field coat. Shop coating may be scratched and chipped to a point where it becomes very time-consuming and costly to "touch-up" the structure after erection.

* * *

If you have any questions about corrosion control or specific problems, write: Koppers Company, Inc., 1450 Koppers Building, Department 100C, Pittsburgh 19, Pa. District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh and Woodward, Ala. In Canada: Koppers Products, Ltd., Toronto, Ontario, and Edmonton, Alberta.

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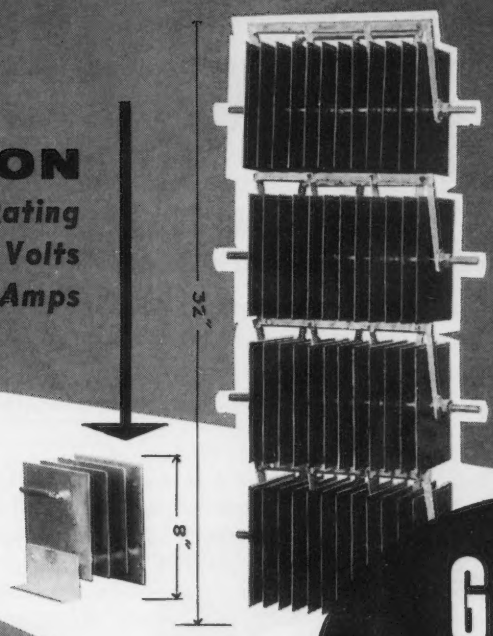

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Longer life, 20% to 50% size and corresponding weight reduction, and 10% or more increase in efficiency are the big advantages of Silicon Cells over Selenium. Current ratings for the usual types of cooling systems will range from 10 to 150 amperes. Current ratings for oil-immersed or forced air heat removal systems are somewhat greater than air convection cooling systems. Silicon Cells are best used in the D. C. output ratings of 25, 50, 75 or 100 volts. (Single phase) or 40, 80, 120, 160 or 200 volts with 3-phase systems.

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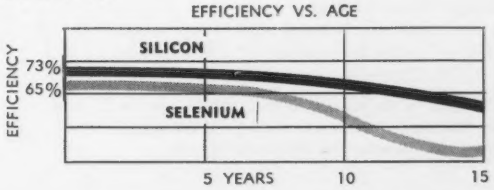
INPUT	250V	250V
LENGTH	15"	19"
HEIGHT	30"	41"
WIDTH	18"	25"
WEIGHT	320 LBS.	400 LBS.



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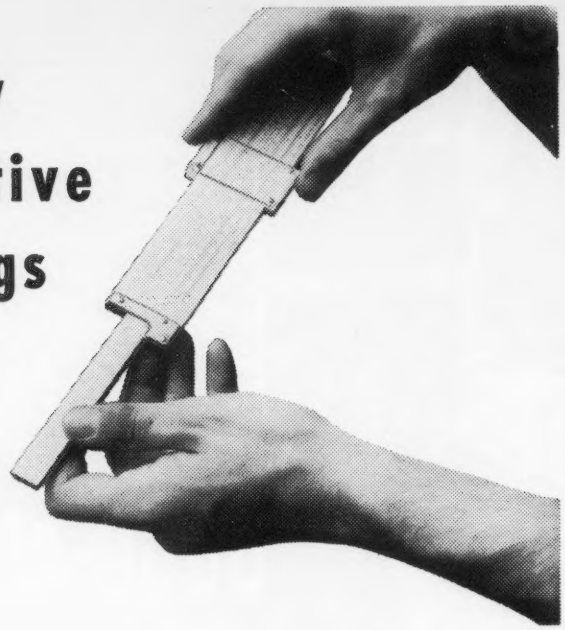

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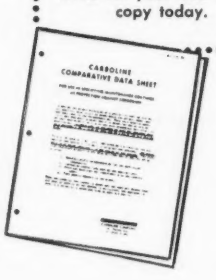

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Houston Section Schedules Programs Through May

Tentative subjects for programs through the May 1957 meeting of the Houston Section have been planned. Subjects for the March meeting will be coatings and for April, inhibitors. The annual section recreational outing will be a barbecue in May.

To promote membership attendance at the 13th NACE Annual Conference and Exhibition in St. Louis, March 11-15, the March Houston Section meeting will be held a week early.

At the February meeting, W. W. Elley, Southwestern Bell Telephone Co., San Antonio, Texas, explained the difficulties of protecting telephone underground plant. Telephone underground lines are mostly bare lead sheathed cables in tile conduit runs and are used principally within the geographic limits of large cities. Corrosion losses in this type of installation have reached alarming proportions, Mr. Elley said. Cathodic protection has helped reduce failures but protection is limited to sacrificial anodes, according to Mr. Elley.

The meeting was held February 12 at John's restaurant with 45 members and guests in attendance.

J. P. Barrett Is Elected

J. P. Barrett, Stanolind Oil & Gas Co., Tulsa, has been elected chairman of NACE's South Central Region. Also named were J. C. Spalding, Jr., Sun Oil Co., Dallas, vice-chairman; J. A. Caldwell, Humble Oil & Refining Co., Houston, secretary-treasurer and W. F. Levert, United Gas Pipe Line Co., Shreveport, assistant secretary-treasurer.

CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at $2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

CERTIFICATES for PAST CHAIRMEN of REGIONS and SECTIONS

Certificates measuring 9 x 12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at $7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

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A. B. Campbell, Executive Secretary

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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THE DURIRON COMPANY, INC./DAYTON, OHIO

ANODE DATA SHEET

Number 3

Fresh Water

Basic engineering information about DURIRON *impressed current anodes for cathodic protection.*

Protection of an Office Building Water Service Tank

THE PROBLEM: The cathodic protection of two 2600 gallon office building water service tanks. Aluminum anodes previously used in the installation had a comparatively short service life and required annual replacement. The continually increasing surface resistance of the aluminum anodes also required periodic rectifier adjustments to maintain an adequate protective current.

THE INSTALLATION: The tank is a single structure divided by a bulkhead to form two separate water storage units of identical size. The anodes were laid out to miss internal bracing, floats, and free-space for hatch opening. A single Duriron Type D (2" x 60") anode was first tested in parallel to fifteen 5 month old aluminum anodes (1-1/16" x 72") to determine its relative merits. Although the Duriron anode had slightly higher surface resistance when first installed, it showed no tendency for this surface resistance to increase and within 2 to 3 months was passing over twice as much current as the average current from the aluminum anodes.

After 311 days of the testing period the original anode proved so successful that all fifteen aluminum anodes (having reached the end of their useful life) were replaced with Duriron Type A (1" dia. x 60" long) anodes. One and one-half standard lengths were joined end to end making each anode assembly 7.5 feet long. Fifteen assemblies, together with the original test anode, were installed as shown in Fig. 2.

The test anode was inspected after more than two years of operation with the following results:

Total energy discharge—8700 ampere hours
Weight loss—3 ounces
Rate of loss—0.19 lbs. per ampere per year
Current density, over a 10 month period—0.14 to 0.21 amps per square foot

THE PERFORMANCE TO DATE: Five of the fifteen Duriron anodes installed on a permanent basis were inspected after 440 days of operation. The following table illustrates the results of this inspection.

Inspection Results After 440 Days Service

Anode Number	Total Energy Discharge (Ampere Hrs.)	Weight Loss (Ounces)	Consumption Rate Lbs./Amp./Yr.	Current Density (Amps per Square Foot)
1	3400	1	0.160	0.21 to 0.28
2	3181	½	0.086	0.20 to 0.27
3	3600	2	0.300	0.22 to 0.30
4	3000	¾	0.045	0.17 to 0.23
5	3400	1½	0.240	0.22 to 0.30

Incidental Data at Inspection Time:

A—Water resistivity in this tank was approximately 14,000 ohm-cm.

B—Average potential impressed on anodes was 25 volts, d-c.

A careful inspection was also made of the submerged joints of the five anodes. While a single neoprene washer appeared to adequately protect the submerged joint, polyethylene or polyvinylchloride tapes were also used over the joints to give further protection. All joints were found to be in excellent condition, although it was concluded that the taping of joints afforded little, if any, extra protection. There was no evidence of attack on the Monel inserts or the Everdur studs.

Corrosion attack on Duriron impressed current anodes is negligible at low current densities under the conditions of this installation. The Duriron anodes showed no appreciable increase in surface resistance during the entire period.

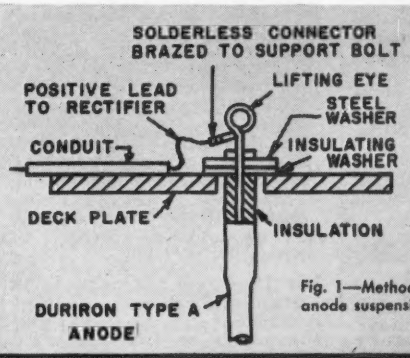

Fig. 1—Method of anode suspension

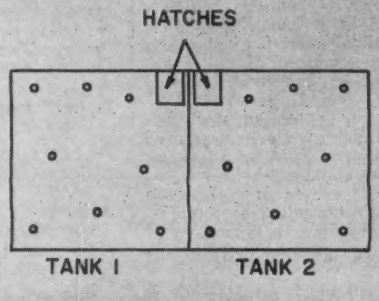

Fig. 2—Illustration of anode spacing

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Gordon Corrosion Conference Set July 15-19

Subject Matter Is Outlined for Annual Meeting

The Gordon Research Conference on Corrosion is scheduled to be held July 15-19 at Colby Junior College, New London, N. H. Sessions are held during morning and evening hours with afternoons off for recreation. Requests for attendance or additional information should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston.

Agenda for the Corrosion Conference is as follows:

July 15—Hydrogen Absorption and Embrittlement. J. J. Harwood, chairman.

Solubility and Diffusion of Hydrogen in Steel, M. L. Hill.

Adsorption of Hydrogen on Metals With Reference to Corrosion and Embrittlement, J. O'M. Bockris.

Hydrogen Absorption and Embrittlement, F. de Kazinczy.

Delayed Fracture and Hydrogen Absorption, B. F. Brown.

July 16—Dependent Corrosion and Oxidation.

Structural Factors Associated with the Oxidation of High Purity Aluminum in Water, W. E. Tragert.

Oxidation of Niobium Binary Alloys, T. N. Rhodin.

July 17—Effects of Radiation on Corrosion, H. E. Draley, chairman.

Effects of Molecular Irradiation on Metal Surface Reactions, M. T. Simnad.

Effect of Radiation on the Corrosion of Zirconium, G. H. Jenks.

Corrosion in Water at High Temperatures, E. C. W. Peryman, chairman.

Atomic Energy Research Establishment, Harwell, England, R. A. U. Huddle.

Behavior of Aluminum and Uranium in Water at High Temperatures, J. E. Draley.

July 18—Corrosion in Water at High Temperatures.

Corrosion of Uranium Alloys in High Temperature Water, M. W. Burkart.

Intergranular Corrosion of Aluminum in High Temperature Water, F. H. Krenz.

Stress Corrosion Cracking of Stainless Steel, M. A. Streicher, chairman.

Current Research and Problems Associated with Cracking Failures of Stainless Steel, J. J. Harwood.

New Research on Austenitic Stainless Steels, H. H. Uhlig.

July 19—Stress Corrosion Cracking of Stainless Steel.

Research at the National Bureau of Standards on Cracking of Stainless Steels, Hugh L. Logan.

Corrosion Cracking of Stainless Steels, A. W. Dana.

Figure 1—Pulled tensile specimen of new cast stainless alloy shows type of fracture associated with metals of good ductility.

New Cast Alloy Has Corrosion Resistance Equal to 18-8's

Better mechanical properties than those of the usual 18-8 stainless steels are claimed by Alloy Casting Institute for its newly developed high-strength cast alloy designated Type CD-4MCu, which has the following composition range: 25-27 chromium; 4.75-6 nickel, 0.04 carbon (maximum) 1.75-2.25 molybdenum; 2.75-3.25 copper; 1 maximum each silicon and manganese.

Corrosion rates for the new alloy are said to be of the same order of magnitude as those for 18-8. M. G. Fontana, Ohio State University, presenting data on tests, reported the corrosion rate in boiling nitric acid very low, with no tendency to increase with time. Straus tests of the new alloy, showed no decrease in angle of bend before cracking after exposure of 72 hours.

No corrosion was shown at room temperature in 10 percent sulfuric acid, 50 percent sulfuric acid or 0.05 percent hydrochloric acid. In 5 percent hydrochloric acid the rate was only 60 mils a year.

TABLE 1—Properties of Two Production Heats of CD-4MCu

Heat No.	HEAT TREATMENT deg. F	HEAT TREATMENT Hours	Tensile Strength psi	Yield Strength psi	Elongation, Percent	Reduction of Area, Percent	Brinell Hardness	Charpy V Notch; ft-lb	Corrosion Rate[c] Mil per Year
R4431	850	4[a]	140,900	100,000	25.0	37.9	302	9.5	6.5
	850	1[a]	135,800	89,000	25.5	50.8	293	30.5	6
	1950	2, W.Q.	112,700	80,700	28.5	48.4	248	104.0	6
	None,	as cast	121,000	83,500	27.0	41.4	262	18.5	18
P1	950	3[b]	140,000	120,000	16.0	...	321	...	6[d]
	2050	1, W.Q.	102,500	85,000	19.0	...	250	...	7[d]
	None,	as cast	.....	.....	....	...	270	...	...

[a] Aging treatment preceded by water quenching after 2 hr. at 1950 F.
[b] Aging treatment preceded by water quenching after 1 hr at 2050 F.
[c] In boiling 65 percent nitric acid. Average of five 48-hour periods; two specimens each.
[d] Average of two 48-hr periods; single specimens.

Interesting Plastics Papers Presented to SPI

Papers interesting to corrosion workers presented at the 12th Annual Exhibit and Conference of the Reinforced Plastic Division of The Society of the Plastics Industry, Inc. February 5-7 included:

Status Report of NACE T-1J on Oil Field Structural Plastics; Performance of Glass-Reinforced Plastic Pipe and Storage Tanks, J. E. Carey.

Quality Control in the Production of Reinforced Plastic Pipe, H. D. Boggs.

Design Data for Reinforced Plastics, Capt. W. E. Dirkes.

A Survey of Recent Development in Resins for Reinforced Plastics, Irving Skeist.

A Survey of New Developments in Reinforcements for Reinforced Plastics, Semond Levitt.

New Developments in Fillers for Reinforced Plastics, George Lubin.

Improvement of Reinforced Plastics by Fibers from New Glasses, J. Frees Brossy, James W. Case, Armand L. Houze, Albert H. Lasday.

Platinum Metals Review Quarterly Is Available

Platinum Metals Review, a quarterly journal published by Johnson Matthey & Co., Inc., 608 Fifth Ave., New York, N. Y. is devoted to current information on the properties and industrial application of platinum and its associated metals. Vol. 1, No. 1, January, 1957 contains article on protection of chemical process equipment, electrodeposited rhodium, creep properties of platinum metal and alloys and others.

An illustrated article on platinum mining in the Transvaal gives interesting historical information. Abstracts of current literature are included in one section.

Copies are available from Matthey & Company.

•

Abstracts from more than 30 sources are used in CORROSION's Abstract Section.

Los Angeles Air Pollution Control Results Are Cited

Results of air pollution control measures in Los Angeles County are cited in the December, 1956 issue of Air Pollution Control District Report, a periodical issued by the Los Angeles Air Pollution Control District. Despite an increase in county population of 200,000, an additional 173,000 motor vehicles and an increase in refinery throughput of 59,000 barrels a day the district said:

Alert levels were reached 10 times compared to 15 times in 1955.

Maximum downtown ozone concentration was 0.60 parts per million vs the all-time record of 0.85 reached in 1955.

Metallic loading of the air was reduced by 40 percent, despite a rise in industries (1949 versus 1956).

The state legislature has been asked for a law regulating auto exhaust control devices.

Electrochemical Society To Meet on May 12-16

The 111th Meeting of The Electrochemical Society will be held May 12-16, 1957 at Statler Hotel, Washington, D. C.

•

Papers are being sought now for NACE's 1958 Conference in San Francisco.

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BOOK NEWS

Arcs in Inert Atmospheres and Vacuum. Edited by W. E. Kuhn. 8½ x 11 inches, cloth. Published December 26, 1956. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. Per copy, $7.50.

Consists of papers presented at the Symposium on Arcs in Inert Atmospheres and Vacuum of the Electrochemics and Metallurgy Division of The Electrochemical Society April 30-May 1, 1956 at San Francisco, Cal.

Thirteen papers are presented covering aspects of arc melting fundamentals, design and operation of arc melting furnaces and chemical applications of arcs. The volume is liberally illustrated, contains significant compilations of tabulated and graphed data and includes numerous references.

Corrosion of Cast Iron and Steel in the Soil. (In Dutch) 26 pages, 8⅜ x 11½ inches, paper. November 1956. Publication 48. Metaalinstituut TNO, Afdeling Corrosie, Delft, Holland. Per Copy F 2.50.

A report on 25 years of study by Corrosion Commission II marking the 25th anniversary of the Commission on October 15, 1956. Contents include: 25 Years of Corrosion Commission II; Discovery of Anaerobic Metal Corrosion in the Soil; Asphalt Bitumens; Practical Results of the Work Done by the Corrosion Commission; Comparisons of Soil Corrosion Resulting From Stray Currents; and Coal Tar.

Paint Faults and Remedies. By H. Courtney Bryson. 184 pages, 6 x 9½. Published by Scientific Surveys, Ltd., Holland House, 140, Cromwell Road, London S.W.7. Per Copy $5.

An alphabetized listing of painting faults and remedies, liberally illustrated. The book is a reprinting of the same subject matter run serially in the monthly periodical Corrosion Prevention and Control. There is an alphabetical subject index.

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Radiation Effects Study

A colloquium on Radiation Effects on Materials will be held March 27-29 on the campus of Johns-Hopkins University, Baltimore by Office of Naval Research, Navy Department and the Martin Company.

Among the papers to be given are:

Radiation Effects on Physical and Metallurgical Properties of Metals and Alloys.

Influence of Radiation Upon Corrosion Behavior and Surface Properties of Metals and Alloys.

Effects of Radiation on Organic Materials.

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Equipment Services NEW PRODUCTS Materials Literature

Zircaloy-2 an alloy of zirconium with small amounts of iron, chromium, tin and nickel is being used by Climax Molybdenum Co., Norristown, Pa., to manufacture tubing for use in nuclear reactors.

•

Plastic Applicators, Inc. opened its Odessa, Texas plant March 1. The plant will supplement the production of the firm's plants at Houston and Harvey, La. The Odessa plant will supply baked-on plastic-coated tubular goods for the oil and gas industries in West Texas and New Mexico. The firm applies phenolic or modified phenolics to tubing to protect it against corrosion and paraffin deposits.

•

Sherosopes, petroleum sulfonates manufactured by the Sherwood Refining Division, Continental Oil Co. will be marketed by Bryton Chemical Division, 630 Fifth Ave., New York 20, N. Y. Sherosope-T, a sodium sulfonate used in rust preventive compounds, will be produced at an expanded rate from a Gretna, La. plant. The material, a 500 plus molecular weight sodium petroleum sulfonate has high activity, uniform quality and high rust prevention, the company says.

•

Borazon, cubic boron nitride manufactured by General Electric Co. scratches diamonds with ease and remains hard at 3500 F, a temperature at which a diamond burns up. Robert W. Wentdorf, discoverer, says the material is in the same general range of hardness as the diamond. X-ray diffraction tests show alternate atoms of boron and nitrogen are packed together almost as closely as carbon atoms in a diamond.

•

Corrplast, Inc., 100 Dayton Ave., Passaic, N. J., has started extruding unplasticized rigid polyvinylchloride pipe ducts and sheets. The firm's products are distributed exclusively by Jos. T. Ryerson & Son, Inc. under the trade name "Ryertex Omicron."

•

Gage Blocks machined to "minus nothing" tolerances are being made by Ellestrom Standards Div., Dearborn Gage Co. The tolerances, plus 8-millionths of an inch, minus nothing for working accuracy blocks and plus 4-millionths, minus nothing for inspection accuracy are said to be the highest ever offered, and the only blocks with all deviations on the plus side.

•

Brea Chemicals, Inc., 714 West Olympic Blvd., Los Angeles 15, Cal., a subsidiary of Union Oil Company of California, will introduce a new polyethylene plastic. The Zeigler-type high-density resin will be produced at a plant operated jointly by Brea and Koppers Co., Inc.

•

Kennametal Grade K501, tungsten carbide with platinum binder is suggested for many uses where platinum is now required by Kennametal, Inc., Latrobe, Pa. Laboratory corrosion tests made by the company showed no measurable loss after seven days in boiling 5 percent nitric and sulfuric acids and a loss of only 74 mg/dm/day in boiling 5 percent hydrochloric acid.

Hyper-Pure Silicon will be made for the first time in a full scale plant by the DuPont Company at Brevard, N. C.

•

General Electric Company's Flight Propulsion Laboratory Dept., Aircraft Gas Turbine Division has announced the development of a new high-strength alloy designated J1300, designed to operate in the 1200-1400 F temperature range. Conceived as a jet engine wheel material, it has a strength-to-weight ratio 25-40 percent better than comparable materials and an operating temperature 100 F higher than materials now used. Statistical methods were used to reduce experimental melts to a minimum.

•

T-Brite, an electrolytic process developed by Temco Aircraft Corp., Dallas, is used to de-scale titanium and bring about a substantial saving in rejected parts. An electrical current is run through titanium while immersed in acid to remove scale. Molten salt method formerly

(Continued on Page 140)

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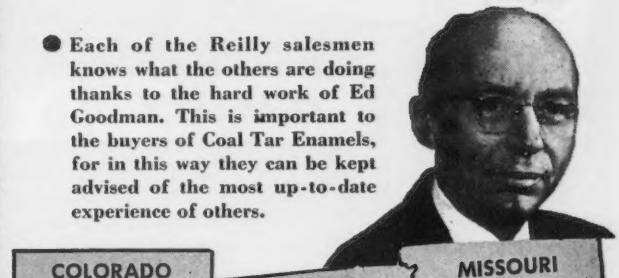

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NEW PRODUCTS

(Continued From Page 139)

used was expensive and caused much hand scrubbing of parts. J. J. Dailey is the developer.

•

Flotrusion, a method of cold flowing metals into tubular forms that require little subsequent machining to hold finished and dimensional tolerances has been developed by Claude C. Slate Co., 1733 Flower St., Glendale, Cal.

•

Magnaflux Corp. has increased the assembly area of its Chicago plant by one-third.

•

Plastic Applicators, Inc., 7020 Katy Road, Houston, is building a new office building and manufacturing plant estimated to cost $500,000. Rubber Applicators, Inc., a wholly-owned subsidiary, also will share the new plant's added facilities. The firm specializes in corrosion resistant linings and coatings.

•

Permaspray Mfg. Corp., League City, Texas has developed a corrosion resistant coating which can be applied in all conventional ways to plant structures exposed to corrosive air and liquid environments. Tests made by the company show the material has excellent resistance, even after 18 months' submerged in hydrochloric acid, caustic soda, salts, gasoline or fuel oils. Three years' exposure in Gulf Coast chemical plants have likewise shown the material to give good results.

•

Saraloy 898, an elastomeric copolymer based on vinylidene chloride, designed to protect metal components of chemical plants has been developed by the Dow Chemical Company's plastic department. The flexible thermoplastic is the first in a new family of materials, according to D. L. Gibb, salesmanager of Dow's plastics department. He said it has extraordinary resistance to a broad range of acids, alkalis, salt solutions and solvents commonly found in storage tanks, processing tanks, medium to large diameter pipes and fittings, fume ducts and hoods. It is supplied in standard 37-inch by 133-inch sheets from 1/16 to 3/16 inch thick. Field installation with adhesive is practical. Saran Lined Pipe Co., 2415 Burdette Ave., Ferndale, 20, Mich. is distributor.

•

Dynel filters are used in pumps handling electroplating and similar industrial solutions to remove particles down to one micron in size. Sethco Mfg. Co., 70-78 Willoughby St., Brooklyn, N. Y. manufactures pumps with the filter using a polyethylene body and a Hypalon impeller. The filter chamber is fabricated of polyvinyl chloride.

•

Concessions to prospect for manganese comprising approximately 2460 square miles have been obtained in Northern Rhodesia by Vanadium Corp. of America near a concession from which the company takes large tonnages of high grade manganese ore.

•

Silicon Diodes are used in rectifiers with capacities up to 1000 amperes manufactured by Christie Electric Corp., 3410 West 67th St., Los Angeles 43, Cal. DC voltage ranges from 6 to 40 are offered. Longer life, lighter weight and resistance to humidity fungus, salt spray, sand and dust are among the advantages claimed for the units over other kinds.

•

Elemental sulfur will be extracted in a pilot plant at the Copper Cliff operations of The International Nickel Co. of Canada, Ltd. The Canadian firm has made an agreement with Texas Gulf Sulphur Co. to investigate the feasibility for recovery of sulfur from sulfur dioxide bearing gases.

•

Micromesh, expanded metals with opening as small as 1/16-inch can be made of any standard sheet material by Designers Metal Corp., 482 East 159th St., Harvey, Ill.

•

Incoloy "T," a new high temperature nickel alloy expected to find wide use in highly stressed parts of jet engine combustion systems has been developed by The International Nickel Co., Inc. A titanium-containing nickel-iron-chromium alloy, produced in sheets, it is designed to operate at temperatures up to 1400 F, has excellent oxidation resistance up to 1600 F. A basic data sheet can be obtained from Reader Service Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

•

Fortiflex, a new resin made under license from Phillips Petroleum Co., will have an unusual combination of heat resistance, toughness and chemical inertness not found in standard polyethylene, to which it is related. Celanese Corp. of America, manufacturer, claims a whole new family of Fortiflex materials will be developed. The manufacturing plant

(Continued on Page 141)

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NEW PRODUCTS

(Continued from Page 140)

is located near the Houston Ship Channel, adjacent to San Jacinto State Park, near Houston.

•

Atlas Powder Company is building a $3 million technical center near the company's general offices at Wilmington, Del.

•

Cathodic Protection Services and Materials, a booklet listing the services of Corrosion Services, Inc., P. O. Box 7343, Tulsa, Okla. is available on request.

•

Corrosion Rectifying Co. has moved into its new offices and manufacturing plant at 5310 Ashbrook St., Houston. Coreco, Inc., and its sister company Electronics International, Inc. share the building which is on a site with ample room for expansion.

•

Electro Metallurgical Company's Ashtabula, Ohio titanium sponge plant is producing sponge at an annual rate of 7500 tons. It is the first titanium plant in the United States to produce the metal commercially by the sodium reduction process.

•

Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Cal. has a new portable millivoltmeter which makes AC measurements to 50 microvolts. Transistors are used to reduce weight, size and give 400 continuous hours of operation by battery.

•

Molded Fiberglass Research Company has completed a 6000-square-foot laboratory housing the research facilities of five companies using molded fiber glass as a component. It is located at 4826 Benefit Ave., Ashtabula, Ohio.

•

Temperature Control units said to be immune to problems involved in handling corrosive liquids are available from Carl Buck & Associates, Essex Falls, New Jersey. A short section of material suitable to the corrosive handled is inserted into the suction line between tank and exchanger pump and a thermal bulb is strapped onto the inserted pipe and covered with insulation. Temperature variations are relayed to a control, distant as necessary from the solutions, where a solenoid valve actuates a steam or coolant line.

•

Trimethyl Aluminum is being produced in pilot plant quantities by U. S. Industrial Chemicals Co., Division of National Distillers Products Corp. The material, which ignites spontaneously in air, is being tested as a fuel and igniter for ram jet and turbojet engines. Also available from the pilot plant is methyl aluminum sesquichloride, and dimethyl aluminum chloride.

•

HMDA-Carbamate, an inner salt of W-amino hexyl carbamic acid, a new vulcanizing agent which permits controlled curing of elastomers and resins capable of being cross-linked with organic polyamides, has been announced by M. W. Kellogg Co., 711 Third Ave., New York 17, N. Y. Developed first for use in vulcanizing Kel-F, it shows promise as an efficient curative agent for other rubbers of the reactive halogen or acrylic type. It is now available to compounders and fabricators.

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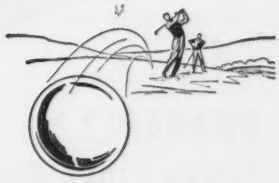

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MEN in the NEWS

Kenneth Fowler has been named Northwest field representative of Perrault Equipment Co.

•

Marcel A. Cordovi, head of the materials and testing department of The Babcock & Wilcox Company's Atomic Energy Division, has been selected as the principal lecturer for a course on the metallurgy of nuclear power reactor materials at Brooklyn Polytechnic Institute.

•

Peter Simmons, Dow Chemical Co., has been elected president; **Haiman Nathan,** Atlas Plastics, vice-president and **R. K. Gossett,** of Gossett & Hill, secretary of the Society of Plastics Engineers. **Jules W. Lindau III,** Southern Plastics and University of South Carolina, was elected treasurer.

•

Alan G. Richards has been appointed director of applications for Bjorksten Research Laboratories for Industry, Madison, Wis.

•

Herbert G. Arlt, Bell Telephone Laboratories, Murray Hill, N. J. has been elected president of Standards Engineers Society.

•

Charles P. McHugh has been appointed director of research and products design at Manhattan Rubber Division, Raybestos-Manhattan, Inc., Passaic, N. J.

•

Fred E. Techmer has been named chief chemist, Insul-Mastic Laboratories, Inc., Summit, Ill. **Eugene D'Asto** has been appointed to head the technical service division.

•

J. Frederic Byers, Jr. has been elected chairman of the board of A. M. Byers Co. B. M. Byers was elected president.

•

Raymon I. Lindberg has been named director of corrosion research for A. M. Byers Co., Pittsburgh. Mr. Lindberg, formerly associated with Sinclair Research Laboratories, Inc. for the past 10 years, also has worked with General American Transportation Corp. and Jos. E. Seagram & Sons. He has been active in NACE affairs, having held the offices of chairman Chicago Section and vice-chairman, North Central Region.

•

Robert F. Connelly is now salesmanager of the Aircraft and Chemical Division, Bray Oil Co., 3344 East Medford St., Los Angeles 63, Cal. in charge of lubrication, corrosion and hydraulics engineering.

•

Malcolm T. McCants has opened consulting engineering offices in the Texas National Bank Bldg., Houston. He is active principally in the petroleum and petrochemical fields. He has been employed by Great Northern Oil Co., St. Paul, Minn. and was general superintendent of Great Southern Chemical Corp., Corpus Christi, Texas for three years.

•

C. J. "Neil" McBride has been appointed director of research for Tubular Lining Corp., Houston. He formerly was chief chemist at Tube-Kote, Inc. and technical director of Plastic Applicators, Inc.

•

E. G. "General" Lee has opened offices as manufacturers' representative handling oil field, industrial and corrosion control chemicals. He formerly was oilfield salesmanager for Diamond Alkali Company.

•

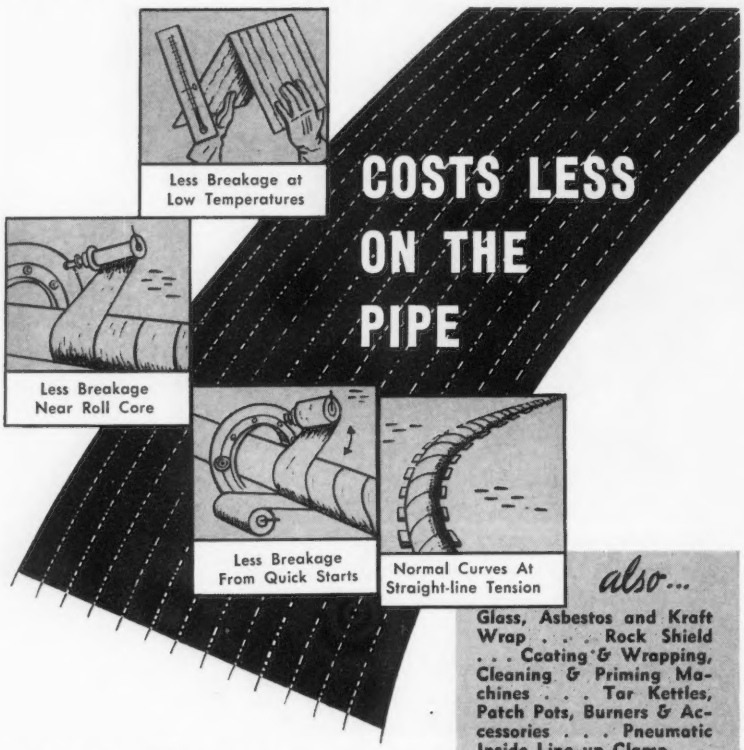
Cathodic Protection Service personnel additions have been made as follows: **Ted Canfield** is now the fourth engineer assigned to the Tulsa office; **Ralph Pass** is now working out of the New Orleans office and **Leslie Dickson** has joined the main office force at Houston. The firm now has twenty in its engineering staff, whose combined engineering experience is over 150 years.

•

John H. Alden has been made assistant chief metallurgist, metallurgical division, Aluminum Company of America. **Howard J. Rowe** has been named chief metallurgist, fabricating division and **Sanford H. Bennett** is now chief industrial engineer for the fabricating division.

NBS Publishes Supplement To Chemical Kinetics Tables

Supplement 1, Tables of Chemical Kinetics, Homogeneous Reactions (National Bureau of Standards Circular 510), issued Nov. 14, 1956 can be ordered from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price is $3.25. Foreign remittances require one-third more for mailing costs. This is the first supplement to the loose-leaf Tables of Chemical Kinetics, Homogeneous Reactions issued in 1951 as NBS Circular 510.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CORROSION ABSTRACTS

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1. GENERAL

1.2 Miscellaneous

1.2.2, 8.9.3, 7.7

An Estimate of Corrosion Losses to Underground Cables and Pipe Lines in Japan. MICHIO TANAKA. *Corrosion,* **12,** No. 10, 513t-514t (1956) October.

An estimate was made of corrosion losses to underground cables and pipe lines in Japan. It was found that such losses over the past few years averaged approximately $200,000 annually. This figure was arrived at by making use of such factors as total length of installations, number of failures per year caused by chemical corrosion, number of failures per year caused by electrolytic corrosion, annual expenditures necessary for replacements and repairs, average repair expenditure per failure and rate of failure due to corrosion per 100 km year. 12362

1.7 Organized Studies

1.7.1

A Classification and Filing System for Corrosion Literature. W. L. MATHAY AND R. B. HOXENG. *Corrosion,* **12,** No. 11, 588t-592t (1956) Nov.

A method has been developed for the classification and filing of abstract punch cards and literature on the subject of corrosion. The method involves the use of an adaptation of the subject filing index devised by the National Association of Corrosion Engineers for use with NACE corrosion abstract punch cards. The NACE index divides corrosion literature into eight main topics, each of which is further subdivided and designates random-number codes to be used in sorting the cards for second-order subdivisions. In the newly-developed classification and filing index, the second-order subdivisions of the NACE index have been generalized to permit the filing of cards according to main fields of interest, such as corrosive environments, preventive measures, and materials of construction. This method of filing, which provides for expansion of existing files and which considerably reduces the time and effort required in sorting for information, may also be applied to other corrosion literature. 12445

2. TESTING

2.1 General

2.1.1, 3.2.2, 6.4.2

Application of the Statistical Theory of Extreme Values to the Analysis of Maximum Pit Depth Data for Aluminum. P. M. AZIZ. *Corrosion,* **12,** No. 10, 495t-506t (1956) October.

Pit depth distribution curves were constructed for 2S aluminum immersed in tap water for time period of two weeks, one, two, four and six months and one year, respectively. The distribution curves were found to consist of two superimposed curves. A "J" shaped curve resulted from pits which initiated and stifled within two weeks of immersion, whereas the other a "bell" shaped curve, resulted from pits that initiated and continued to propagate. The "bell" shaped curve retained its shape and moved in the direction of increasing pit depth. After about two months the majority of these latter pits ceased propagating, the mode of the bell shaped curve became stationary, and only a small number of the deeper pits continued to propagate, the tail of the distribution curve lengthening with time.

The maximum pit depths obtained on each of replicate samples were analyzed by the statistical theory of extreme values using the appropriate probability paper and were found to fit the extreme value distribution:

$$\Phi y = e^{-e^{-y}}$$

from this it was shown that the maximum pit depth is linear in the logarithm of the exposed area thus providing a rational method of extrapolating pitting data obtained in the laboratory on small samples to large scale field installations. This fit of maximum pit depth data to the extreme value distribution also makes possible the extraction of more information from a limited number of pit depths than has been possible heretofore. 12342

2.3 Laboratory Methods and Tests

2.3.7, 5.9.4

Volumetric-Gravimetric Determination Method of the Oxide Film on Electropolished Aluminum. P. V. SHCHIGOLEV. *Zavodskaya Laboratoriya* (Factory Lab., USSR), **21,** 1474-1476 (1956); *Chem. Absts.,* **50,** No. 12, 8431 (1956) June 25.

To measure film thickness, two samples, one mechanically and one electrically polished, are placed in 0.3-0.5N sodium hydroxide. The hydrogen evolved is collected in a measuring gas burette. When the two samples have an equal area, the test is continued until equal volumes of gas are collected; when the areas are not equal, the evolution is continued until equal volumes/unit area of the samples are collected. The samples are weighed on ultrabalances to within 0.01 mg before and after the sodium hydroxide treatment. The film thickness on 99.995% pure aluminum formed when varying the length of electropolishing the metal in an electrolyte composed of sodium carbonate 150 and anhydrous sodium phosphate 100 g./l. at 90 C, 3.5 amp./sq. dm. c.d., 14-16 v.e.m.f. The length of electropolishing varied between 0.5 and 20 minutes. The weight of the film was found to be almost constant, with no more than occasional deviations from the average.—ALL. 12591

2.3.7, 6.6.7, 6.6.8

Testing of Silicone Rubber at Elevated Temperatures. A. J. DEFRANCESCO. Connecticut Hard Rubber Co. U. S. Wright Air Development Center, January, 1956, 41 pp. Available from: Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121192)

Anticipating a future need in supersonic aircraft for elastomeric compounds which will perform effectively at high temperatures, researchers designed and constructed an apparatus to measure physical properties of silicone rubber in temperatures up to 400 F. Tensile strength, elongation, and tear strength at room temperature, 212 and 400 F are compared in the report for 15 commercial silicone compounds. 12389

2.3.7, 6.6.8

Non-Destructive Mechanical Test for Degradation. C. D. DOYLE AND C. S. DUCKWALD. *Modern Plastics,* **33,** No. 7, 143-144, 146, 148, 153-154 (1956) Mar.

Low amplitude vibrational test proved eminently satisfactory as nondestructive method for measuring decline of mechanical properties during heat ageing of glass cloth laminate made with triallyl cyanurate polyester. Change in resonant frequency was regular and indicated that degradation process is diffusion controlled,

with apparent activation energy of 22.6 kcal.—BL. 12405

2.3.9, 4.4.8

Corrosion Testing by the Polarographic Method. K. OKANO, Y. OTA, Y. KITAMURA AND S. YAMASHITA. *Corrosion Engineering*, 5, No. 1, 37-38 (1956) Feb.

Application of a polarographic method to corrosion testing based on voltage-ampere curves. Corrosion resisting properties of stainless steel and mild steels in sodium glutaminate solution are compared.—JSPS. 12536

2.4 Instrumentation

2.4.2, 2.3.4

Apparatus for Visual Study of Corrosion by Hot Water. DANIEL R. GRIESER AND EUGENE M. SIMONS. *AIChE Journal*, 2, 215-218 (1956) June.

A windowed autoclave was designed to provide a pictorial representation of the corrosion phenomenon while it is occurring. The instrument affords a relative evaluation of the influence of such variables as geometry, alloying, type of bonding, water temperature and water impurities on corrosion rate. Table, diagrams, photographs, graphs. 1 reference.—BTR. 12434

2.4.3, 6.2.5, 3.2.2

A Nondestructive Test for Intergranular Corrosion in Stainless Steel Tubing. RICHARD C. ROBINSON. E. I. du Pont de Nemours & Co. U. S. Atomic Energy Comm. Pubn., DP-153, March, 1956, 15 pp. Available from: Office of Technical Services, Washington, D. C.

An eddy current instrument is described which indicates the relative degree of intergranular corrosion present in austenitic stainless steel tubes. The instrument is applicable to the testing of installed tubing. Differences in resistivity of 1% were detected between sample tubes and standard tubes of stainless steel. A sample judged to have very slight intergranular corrosion showed a 14% increase in resistance while a severely corroded sample showed a 286% increase. (auth).—NSA. 12581

2.6 Preparation and Cleaning of Specimens

2.6, 2.1.3, 2.3.1

A Systematic Scheme for Examining Corroded Metal Specimens. J. B. COTTON. *Corrosion Technology*, 3, No. 5, 141-145 (1956) May.

Systematic scheme includes collecting information on history of sample, selection of material for ancillary examination, visual examination, metallurgical examinations for check on structure of metal, spectrographic and wet chemical analyses for check on composition of metal, micro-chemical examination of corrosion products, electrochemical tests, x-ray examination for additional information on nature of corrosion products and metal structure, electron diffraction for identification of surface films, testing of physical and mechanical properties and, finally, proper assembly of information. Examination of tubes removed from heat exchangers is used to illustrate various analysis methods. Photomicrographs show fracture of brazed joint between aluminum brass tube and silicon-bronze header tank as well as stress- corrosion failures and fatigue failure in α brass. Charts present micro-analytical scheme for application to corrosion products removed from aluminum brass condenser tubes which had carried sea water.—INCO. 12395

2.6, 2.3.6, 6.3.4

Electro-polishing and Electro-etching a Sintered Cobalt Alloy. E. R. PERRY. *Metallurgia*, 53, No. 319, 231-233 (1956) May.

Due to its corrosion resistance, slight porosity and susceptibility to structural change on deformation, sintered Vitallium presents difficulties in preparation of microscopic specimens. Details are given of techniques developed for polishing and etching electrolytically. Photomicrographs.—INCO. 12518

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2, 6.2.4, 6.2.3, 1.6

An Investigation of the Effects of Hydrogen on the Brittle Failure of High-Strength Steels. E. R. SLAUGHTER, E. E. FLETCHER, A. R. ELSEA AND G. K. MANNING. Battelle Mem. Inst. U. S. Wright Air Development Center, Tech. Rept. 56-83, April, 1956, 53 pp. Available from: Office of Technical Services, Washington, D. C. (Order PB 121357.)

Investigation of hydrogen on delayed, brittle failure of SAE 4340, 1040 and 4140 high-strength steels by use of room-temperature stress-rupture tests on unnotched, cathodically charged specimens. Principal variables were stress, strength level, structure, composition and hydrogen content. Time for failure to occur decreased as the strength level of steel or applied stress was increased, but changes in structure or composition had little effect on the time to failure. Martensitic and bainite reactions were unaffected by variations in hydrogen. Diffusion of hydrogen through cathodically charged steel was investigated. Stress had no measurable effect on diffusion or distribution of hydrogen in steel. Sustained uniaxial tensile stress is sufficient to cause a delayed, brittle failure in the presence of sufficient hydrogen. Illustrations, 13 references.—INCO. 12599

3.2.2, 6.3.15

Hydrogen Embrittlement of a Commercial Alpha-Beta Titanium Alloy. E. J. RIPLING. *J. Metals* (Trans. AIME), 8, No. 5, Section 2, 502-503 (1956) May.

Hydrogen embrittles α-titanium by rais-

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ing transition temperature and makes it sensitive to increased strain rate. β-titanium can tolerate large amounts of hydrogen without severe mechanical damage. α-β alloys however are embrittled by hydrogen, being sensitive not to increased strain rate as in α-titanium but to decreased strain rates, as found in the hydrogen embrittlement of steels. Author's work on α-β alloy 140A confirms last point.—BNF. 12587

3.2.2, 6.4.2, 4.6.2

The Intergranular Corrosion of Aluminum in Superheated Steam. C. Groot and R. E. Wilson. Hanford Atomic Products Operation. U. S. Atomic Energy Comm. Pubn., HW-41797, May, 1956, 18 pp.

Intergranular attack is quite localized in the earlier stages. Effects of temperature, pressure and composition are shown. Lack of iron results in poor resistance to intergranular attack.—MR. 12466

3.2.3, 3.5.9, 6.2.5

The Structure of Oxide Scales on Chromium Steels. H. J. Yearian, E. C. Kandell and T. A. Longo. *Corrosion,* **12,** No. 10, 515t-525t (1956) Oct.

The structure of the oxide scale formed on commercial chromium steels containing 5 to 26 percent chromium when oxidized in air or oxygen at temperatures from 700 C to 1160 C for times up to 100 hours was determined by X-ray diffraction methods, supplemented in some instances by chemical analysis. Two distinct types of scale were observed: A type scale occurs when the rate of metal loss is less than approximately 10 mg/cm²/day, and B type when the attack rate is in the excessive range. For exposures near the critical conditions an initial A type scale transforms to B type during oxidation.

The essential component of A type scale is Cr_2O_3. This is usually accompanied by αFe_2O_3 in an amount which increases with the iron content of the alloy (i.e., with rate of attack). At high temperatures or long oxidation times, dilute solid solutions of each of these phases in the other are formed. When the alloy contains a few tenths percent of manganese, the A type scale may also include copious amounts of $MnCr_2O_4$ especially for high chrome alloys and for low temperature oxidations in air.

B type scale is more complex than A scale and may be considered as two layers. The outer layer is duplex and is similar in all respects to the Fe_3O_4 and Fe_2O_3 layers of the scale on pure iron. The major constituent of the inner layer, corresponding to the FeO layer on pure iron, is a solid solution, $FeFe_{(2-x)}Cr_xO_4$, of the spinel type. Throughout most of the layer x varies slowly, but near the metal it rises rapidly to $x = 2$ and near the Fe_3O_4 layer it falls rapidly to $x = O$. The mean value of x lies in the range of about 0.5 to 1.5. The greater the chromium content of the alloy, the higher the temperature and the longer the time of oxidation, the larger is the value of x. In cases of very high attack the series of spinels is accompanied by a series of wustites which are modified by chromium additions ranging downward to zero at the Fe_3O_4 layer. For 10 to 20-hour oxidations at 925 C and at 1000 C the chromium fraction of total metal in the inner layer is about 1.8 times its value in the alloy, whereas the excess is only about one percent in the scale as a whole.

The experimental data are compared and contrasted with existing information and are qualitatively interpreted by use of a tentatively proposed iron-chromium-oxygen phase diagram and a special theory of alloy oxidation. 12340

5. PREVENTIVE MEASURES

5.4 Non-Metallic Coatings and Paints

5.4.5, 8.10.3

Corrosion and the Protection Against Corrosion in Mining: Protection by Coal Tar Products. F. Eisenstecken. *Werkstoffe u. Korrosion,* **7,** No. 6, 309-321 (1956) June.

After presenting data on losses of ferrous materials due to rusting, different effects of corrosion on cast iron and steel are discussed. Technological structure of steel influences the corrosive action and formation of protective layers is affected by alloy constituents (sulfur, phosphorus, copper, chromium, nickel). Under certain conditions mill cinders promote pitting corrosion. To avoid these effects and promote adhesion of synthetic surface coating, oxide layer must be removed. Article discusses use of tar products as anti-corrosion agents, especially in mining field. Protective effects of solvent and emulsion combination paints are considered. Use of synoplasts is gaining interest. These materials are suitable for protection of buried pipes and are applicable at the installation site. Adhesiveness of hot plastic materials is increased by spraying application. Illustrations.—INCO. 12383

5.4.7

Flame Spraying Non-Metallic Protective Layers on to Metal Surfaces. H. Reininger. *Industrial Finishing,* **9,** No. 92, 380-384 (1956).

Details of flame-spraying of non-me-

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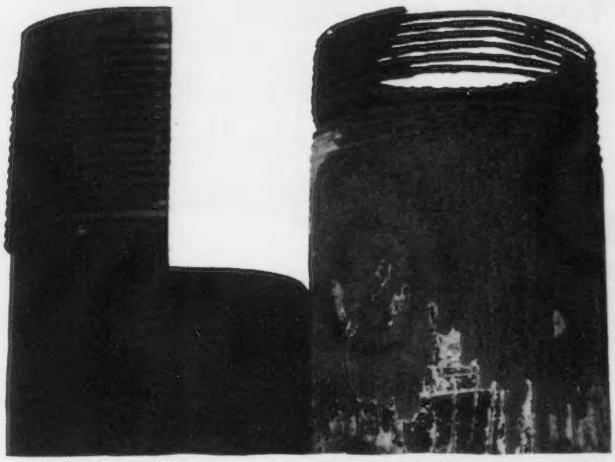

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tallic protective layers such as polyethylene, polyacrylates, polyamides, etc., are given.—RPI. 12546

5.4.7
Electrophoretic Application of Organic Finishes. J. J. SHYNE. *Org. Finishing*, **17**, 12-14 (1956) May.
Procedures for electrophoretic deposition of resins from aqueous and nonaqueous suspensions; merits of both types of suspensions. Diagram, graph, table, 17 references.—MR. 12584

5.4.8, 2.3.4
Anti-Fouling Paint Studies. J. B. BALLENTINE, W. H. STEWART, MARVIN O. YEITER AND A. L. ALEXANDER. *Ind Finishing* (London), **9**, 479-499, 501-503 (1956) Apr.
An investigation of the inherent errors in leaching rate measurements. Tables. —BTR. 12424

5.4.10
Anticorrosive Plastic Coverings. (In French.) L. REMY. *Corrosion et Anticorrosion*, **4**, No. 5, 217-221 (1956) June.
Shortcomings of bituminous coatings on buried metals. True protection against corrosion only obtained by using several layers of material, each with a particular function. The layer in direct contact with the metal protects against chemical and electrical action.—BTR. 12544

5.6 Packaging

5.6.1
Corrosion of Packaged Articles. F. A. PAINE. *Corrosion Technology*, **3**, No. 6, 191-193 (1956) June.
Considerations to ensure best and most economic teachnique in packaging. Table, photographs, 2 references.—BNF.

5.8 Inhibitors

5.8.1
Inhibition and Inhibitors. HELLMUTH FISCHER. *Industrial Finishing* (London), **9**, 486 + 5 pp. (1956) April.
How corrosion inhibitors function; technical applications. Diagrams.—MR.

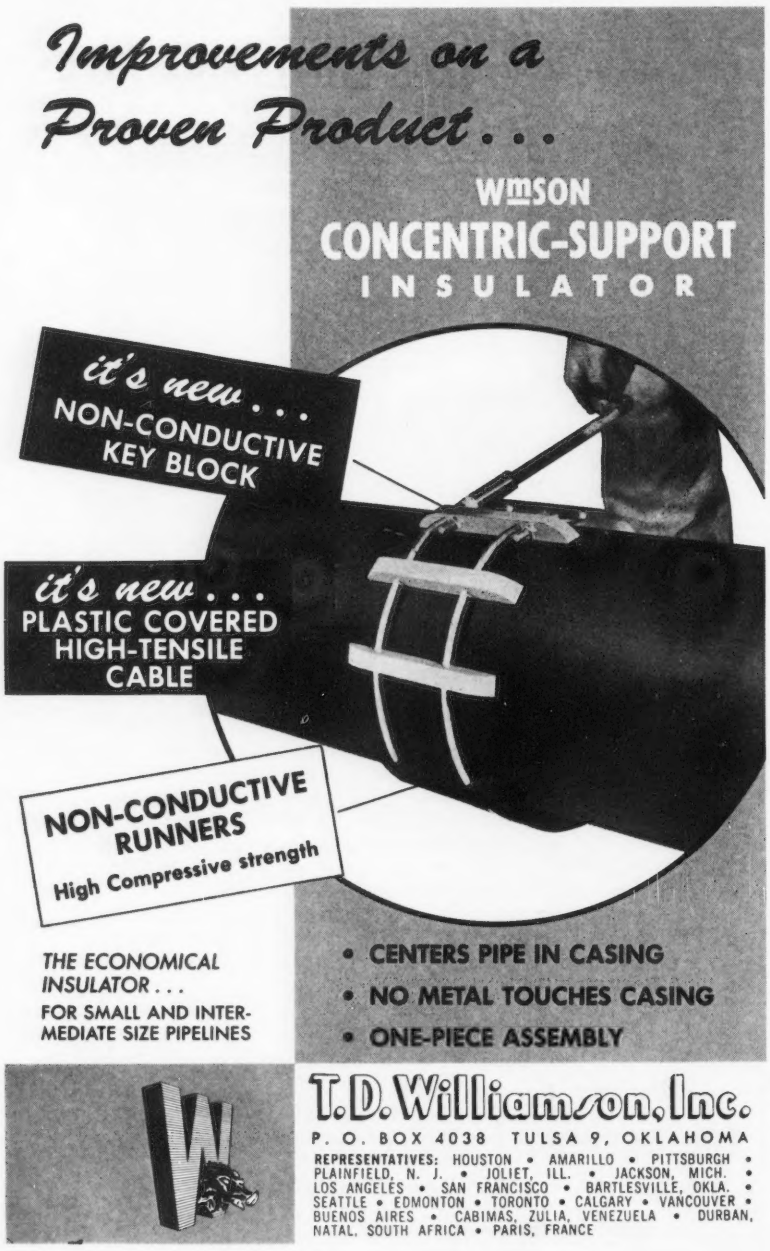
5.8.1, 2.3.4, 2.3.5
Laboratory Method for Corrosion Inhibitor Evaluation. G. A. MARSH AND E. SCHASCHL. *Corrosion*, **12**, No. 11, 534t-538t (1956) Nov.
A screening method has been developed which permits rapid, convenient testing of inhibitors. Unlike weight-loss methods, this new method is well adapted to follow non-linear corrosion-time curves, such as those commonly found when adsorption-type inhibitors are used. The method makes use of quart bottles containing the corrosive agents; the bottles are rotated end over end at about three rpm. This rotation brings about alternate immersion of test probes where the corrosive system consists of two or more phases. The test probes are used to follow the course of corrosion without requiring the bottles to be opened. A probe consists of a corroding specimen (metal ribbon) to which is attached a protected specimen serving as a temperature-compensating element. These specimens form two arms of a resistance measuring bridge. Electrical leads, brought through the rubber stopper to the outside of the bottle, permit the probe to be connected when desired to a bridge circuit which internally converts any change in resistance to loss of metal thickness. The corrosion loss in millionths of an inch is read directly from a meter and can be followed conveniently during the course of the test. An application of the method in testing gasoline rust inhibitors is discussed. 12455

5.8.2
Corrosion Protection of Parts by Means of Vapor-Phase Inhibitors. (In Czech.) L. CERVENY. *Strojirenstvi*, **6**, No. 1, 44-47 (1956) Jan.
Properties and technology of vapor-phase inhibitors. Tests of the effectiveness of dicyclohexyl amine-nitrite as a rust inhibitor, under chemical-industry, marine, and other conditions. Photographs, table, graph, 6 references.—BTR. 12406

5.8.3
The Action of Inhibitors During the Dissolution of Iron in Alkaline Solutions. S. D. LEVINA. *J. Applied Chem., USSR* (Zhur. Priklad. Khim.), **29**, No. 9, 1353-1358 (1956).
An experimental study of the effect of silica gel, sodium phosphate, and tannin on electrochemical activity. One table, 5 figures, 5 references.—ATS. Translation available from: Associated Technical Services, P. O. Box 271, East Orange, New Jersey. 12494

5.9 Surface Treatment

5.9.4
Investigations Concerning the Chromium Content of Black Coatings on Aluminum. Application of Radioactive Chromic Acid. (In Italian.) L. GUERRESCHI AND R. ROMITA. *Alluminio*, **25**, No. 7/8, 333-336 (1956) July-August.
Tracer studies were used for the ex-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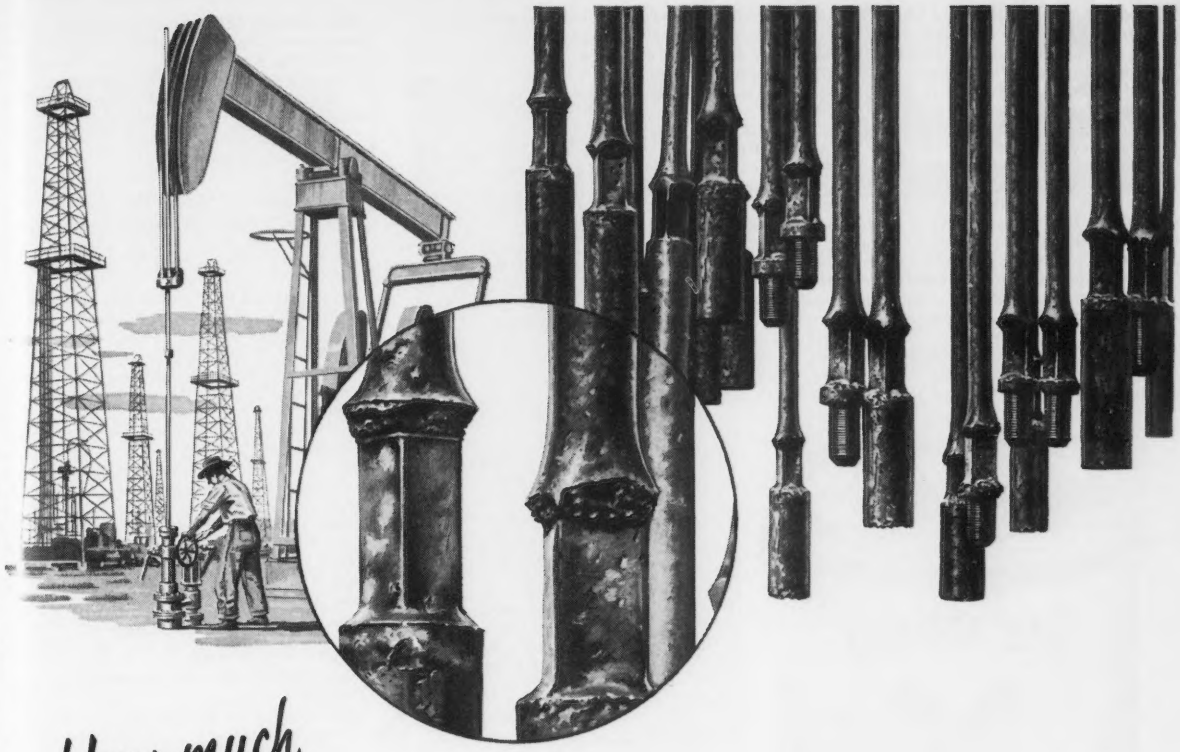

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perimental investigation of the formation of black and greyish brown deposits on aluminum anodized with alternating current in a chromic acid bath. The electrochemical process was carried out with a chromic acid electrolyte prepared from radioactive chromium. The isotope used for this purpose, Cr^{51}, decays with orbital electron capture, accompanied by the usual X-ray phenomena, to vanadium, V^{51}, which, itself in the excited state, emits γ radiation. The conditions of this nuclear process are outlined and the method of counting and the experimental apparatus are discussed in detail. From the activities measured, conclusions are drawn regarding the chromium content of the deposits of both types. The different coloring of these coatings, due to their chromium contents, is attributed to the action of two distinct mechanisms: chemical adsorption in the case of greyish brown deposits and well-defined electrolytic process governing the formation of the black.—ALL. 12467

5.9.4, 2.3.7

Reducing Frictional Resistance and Wear of Steel: Use of Sulphide-Impregnated Surfaces. L. MARSHALL AND S. J. MANSELL. *Engineering*, **181**, 425-428 (1956) June 1.

Results of investigations into claims made for Sulfinuz process of Societe d'Application des Traitments de Surfaces (SATS process). Note is given on process and bath compositions used. Tests were mare on 1% carbon-1.5% chromium steel, using a 4-ball test machine. Details of technique and results are given. Further tests were made on a 1.18% nickel-0.62% chromium-0.78% manganese steel using a Faville-Lavally friction-testing machine. Notes on nature of sulfide film formed on mild and martensitic stainless steels, and appendices on mathematics of the 4-ball and Faville-Lavally test machines are included.—INCO. 12535

5.9.4, 6.3.6

The Nature of the Film Formed on Copper During Electropolishing. E. C. WILLIAMS AND MARJORIE A. BARRETT. *J. Electrochem. Soc.*, **103**, No. 7, 363-366 (1956) July.

The thin film shown by Hoar and Farthing to exist on the surface of copper during electropolishing in orthophosphoric acid has been found, by electron diffraction methods, to be composed of a phosphate of copper. This evidence would appear to confirm the basic assumption of Elmore's theory of electropolishing of a limit to the solubility of copper in the boundary layer of electrolyte. Since the film is soluble in phosphoric acid in the absence of an applied potential, this limit is attributed to a decrease in hydrogen ion concentration at the anode surface during polishing. 12188

5.11 Design—Influence on Corrosion

5.11, 3.5.8

Significance of Fatigue Data in Design of Pressure Vessels. T. J. DOLAN. Paper before Am. Welding Soc. Nat'l. Spring Meeting—Am. Soc. Mech. Engrs. Metals Eng. Div. Conf., May 7-10, 1956. *Welding J.*, **35**, No. 5, 255s-260s (1956) May.

General considerations cover types of surface defects, notches and abruptness of changes in contour which determine localized stresses leading to fracture. Elimination of excessive stress raisers by improvement of design and careful control of fabrication methods and operating procedures of vessels intended for long life, are discussed. Recent data from fatigue studies are reviewed from viewpoint of their inferences in use of high-strength steels and increased design stresses. Difficulties in interpretation of laboratory fatigue data for quantitative design of full-scaled structures are discussed and related to scatter in fatigue life and factors affecting fatigue strength. Graphs, 22 references.—INCO. 12385

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.5

Stabilisation of Titanium-Stabilised Corrosion-Resistant 18/9 Chromium-Nickel Cast Steels. R. POSPISIL and another. *Hutnicke Listy*, **11**, No. 4, 218-225 (1956).

Effect of titanium on stabilization of 18/9 steel against intercrystalline corrosion and on ferrite content. Effects of temperature and annealing time on ferrite content and effects of temperature and precipitation-annealing time (before intercrystalline corrosion test) on precipitation of sigma phase from ferrite are discussed. Cast steel can be titanium-stabilized. Advantage of stabilization annealing of castings is confirmed.—INCO. 12529

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48a

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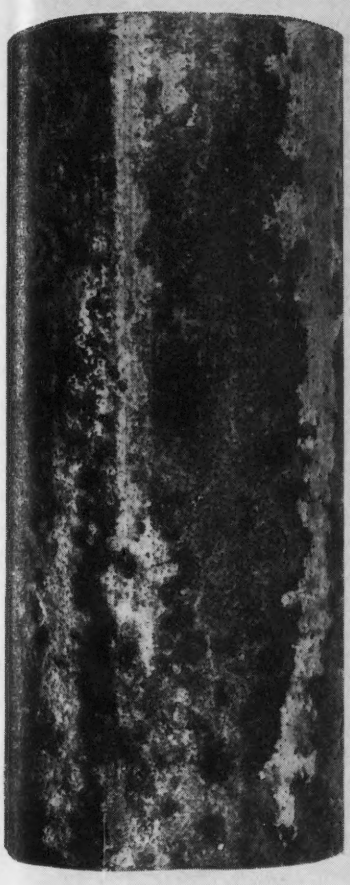

65
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Longitudinal photomicrograph U-2-3 (100x) shows a typical area—parallel to rolling—of the microstructure observed in the subject 1¼" wrought iron pipe.

Metallurgical Report 1517—Condensate Return Line*

This report deals with the metallurgical examination of a length of 1¼ " wrought iron pipe, submitted to our laboratory for investigation and comment.

The outer surface had a tightly adherent oxide coating and was found to be in excellent condition. A 4-inch long piece of the sample was split longitudinally into two half-sections. The interior surface was covered with a rust film; no localized pitting or grooving was observed.

Chemical composition of the pipe sample is as follows: Carbon—.027%; Manganese—.050%; Phosphorus—.217%; Sulphur—.026%; Silicon—.150%; Iron Silicate—3.98%.

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*Name of actual installation given on request.

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6.2.5

The Corrosion Properties of Chromium-Nickel-Mangaese Austenitic Stainless Steels. W. G. RENSHAW AND R. A. LULA. Paper before ASTM, 59th Ann. Mtg., June 17-22, 1956. Am. Soc. Testing Materials Preprint No. 81, 1956, 24 pp.

Deals with corrosion properties of AISI 201 and 202 and some lower carbon and higher chromium grades (chemical composition range: 15-21 Cr, 2-6.5 Ni, 5-17 Mn). Influence of individual elements chromium, nickel and manganese was evaluated. Resistance to various corrosive media, 65% nitric acid, glacial acetic acid, 10% phosphoric acid, concentrated sulfuric acid, 10% citric acid, 20% salt spray, boiling 42% magnesium chloride, 50% lactic acid and 10% oxalic acid, was determined. Corrosion properties of sensitized material, and relation of carbide and nitride precipitation, were studied. Nickel provides improvement in resistance to general corrosion and is especially effective in promoting resistance to local attack. Manganese exerts little influence through 3-14% range covered. Resistance to intergranular corrosion in the sensitized condition is increased by decreasing carbon content. Tables, graphs, photomicrographs.—INCO. 12557

6.2.5

Surface Finishes for Stainless Steels. K. M. HUSTON. *Products Finishing,* **20,** No. 10, 24-30, 32, 34, 36, 38 (1956) July.

Discussion of factors to be considered in finishing stainless steels emphasizes knowledge of grade of steel as essential to setting up procedures for handling in the finishing process. Factors causing corrosion of steel surfaces are discussed and preventive measures are given. Best means of scale removal and cleaning of surface dirt and grease accumulations and the process of passivation are described. Do's and dont's of grinding, polishing and buffing are given. Electropolishing, coloring and plating of stainless steels are described. Photos.—INCO. 12475

6.2.5

Evaluation of Type 304 Stainless Steel as a Substitute for Type 347. R. F. KORNIG. Knolls Atomic Power Lab., Schnectady, N. Y. U. S. Atomic Energy Comm. Pubn., AECD-3890, November 3, 1952 (Declassified with deletions January 5, 1956), 18 pp. Available from: Office of Technical Services, Washington, D. C.

Type 347 stainless steel was selected for SIR applications requiring resistance to corrosion in sodium on the basis of limited corrosion data and extrapolation of experience in aqueous media. Subsequent testing indicated that carbide stabilization was not necessary for good resistance to corrosion in sodium. Evaluation of the unstabilized grade of 18-8 stainless steel, Type 304, was intensified because it offered a number of advantages over Type 347. Type 304 was more readily available, required fewer strategic materials, was less expensive and was reported to be weldable with less difficulty. From the results of this investigation, it appears that Type 304 can be submitted for 347 for all SIR applications where the slightly higher elevated temperature strength of 347 is not required. (auth)—NSA. 12489

6.2.5

Aspects of Corrosion-Resisting Steel Castings. W. G. BOUSTRED. Paper before Inst. Brit. Foundrymen, So. African Branch. *Foundry Trade J.,* **100,** No. 2069, 409-412; disc., 412 (1956) June 7.

Author outlines main types of stainless steels and discusses chemical compositions and various treatments used to stabilize the structures. Proper balance of composition to assure maximum corrosion resistance is discussed. Direct arc and high frequency induction melting and proper techniques in casting stainless steels are covered.—INCO. 12381

6.2.5, 3.8.3

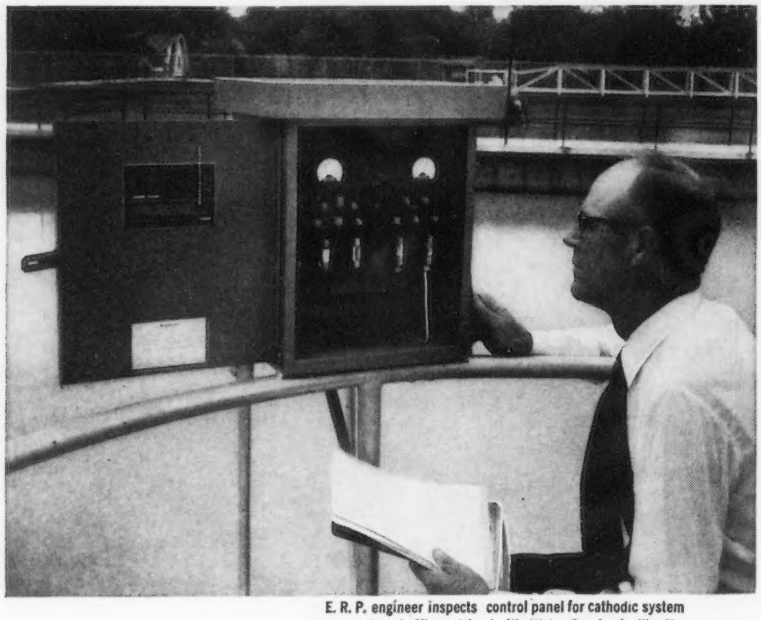
Stabilizing of Passive State of Austenitic Chromium-Nickel Steels by Means of Anodic Polarization in Boiling 4N Sulfuric Acid. (In German.) CARL CARIUS. *Arch. Eisenhuttenw.,* **27,** No. 6, 401-412 (1956) June.

Potential measurements in oxygen containing 4N sulfuric acid at room temperature and the boiling point. Study of passivation. Graphs, diagram, table. 24 references.—BTR. 12398

6.2.5, 3.2.2, 2.3.2

The Explanation of the Intergranular Corrosion of Chromium-Nickel Steel. V. CIHAL et al. *Hutnicke Listy,* **11,** No. 4, 225-230 (1956).

Degree of etching of intergranular mass depends on amount of precipitated chromium carbides and on potential of specimen while being etched. Potential-polarization curves for 18/8 steel and 36% nickel-iron alloy and results of electrochemical observations compared with standard intergranular corrosion test are given.—INCO. 12387



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6.2.5, 3.7.2, 3.2.2

Study of Influence of Titanium on the Intergranular Corrosion of 18/9 Chromium-Nickel Stainless Steel. V. CIHAL AND RUDOLF POSPISIL. *Hutnicke Listy,* **11,** No. 5, 284-290 (1956) May.

Study of relation of abnormal heat-treatment, at very high temperatures, of titanium-stabilized 18/9 steels to intergranular corrosion after heating at 550-700 C. Titanium carbide begins to dissolve at higher temperatures. At 650 C mainly $(CrFe)_{23}C_6$ is precipitated and steel is susceptible to intergranular corrosion.—INCO. 12403

6.2.5, 3.7.3

Effect of Hardening and Tempering on the Corrosion Resistance of 13% Chromium Steel. E. A. OLDFIELD AND G. B. GRAVES. *Metal Treatment & Drop Forging,* **23,** No. 129, 211-215 (1956) June.

Effect of prehardening structure, hardening temperature and time, tempering temperature and time and carbon content on the hardness of chromium steels was investigated. In particular the influence of tempering time and temperature (within 500-700 C) on resistance to corrosion by 5% nitric acid + 1% hydrochloric acid mixture was determined. An empirical equation matching this relationship is suggested. Tempering temperature producing minimum corrosion resistance is dependent upon tempering time; the shorter the time, the higher the temperature necessary to cause loss of stainless properties. For given hardened structure, maximum loss of corrosion resistance occurs at same hardness, irrespective of tempering time and temperature. When sensitized at high tempering temperatures, 13 chromium steel hardened from high temperature is more susceptible to corrosion than steel hardened from low temperature. Graphs.—INCO. 12545

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.15, 4.3.2

On the Chemical Corrosion Properties of Commercially-Pure Titanium. Part II. Y. KONDO. *Sumitomo Metals,* **7,** No. 4, 1-9 (1955) October.

Corrosion resistance of commercially-pure titanium, 13 chromium stainless, high-purity aluminum and electrolytic tough-pitch copper to mixed reagents such as HCl-HNO_3-H_2O, H_2SO_4-HNO_3-H_2O, H_3PO_4-HNO_3-H_2O, H_2O_2-HNO_3-H_2O and HNO_3-HF-H_2O was studied. Corrosion resistance to titanium to HCl-HNO_3-H_2O, H_2SO_4-HNO_3-H_2O and H_3PO_4-HNO_3-H_2O is excellent and far superior to that of other materials. Resistance of titanium to H_2O_2-HNO_3H_2O is inferior to that of 13 chromium stainless and resistance to HNO_3-HF-H_2O is poor. Some surface-treatments improve corrosion resistance of titanium. Purity, fabrication and heat-treatment have no effect.—INCO. 11737

6.3.15, 6.2.5, 6.4.2, 6.3.6

On the Chemical Corrosion Properties of Commercially-Pure Titanium. Part I. Y. KONDO. *Sumitomo Metals,* **7,** No. 1, 35-40 (1955) Jan.

Corrosion resistance at room temperature of commercially pure titanium, 13% chromium stainless steel (0.25% nickel), high-purity aluminum and electrolytic tough-pitch copper in various concentrations of 38 chemical reagents and in aqua regia, sea water, commercial ink and developing and fixing solution for photographs was investigated. Results are tabulated. Titanium is attacked by

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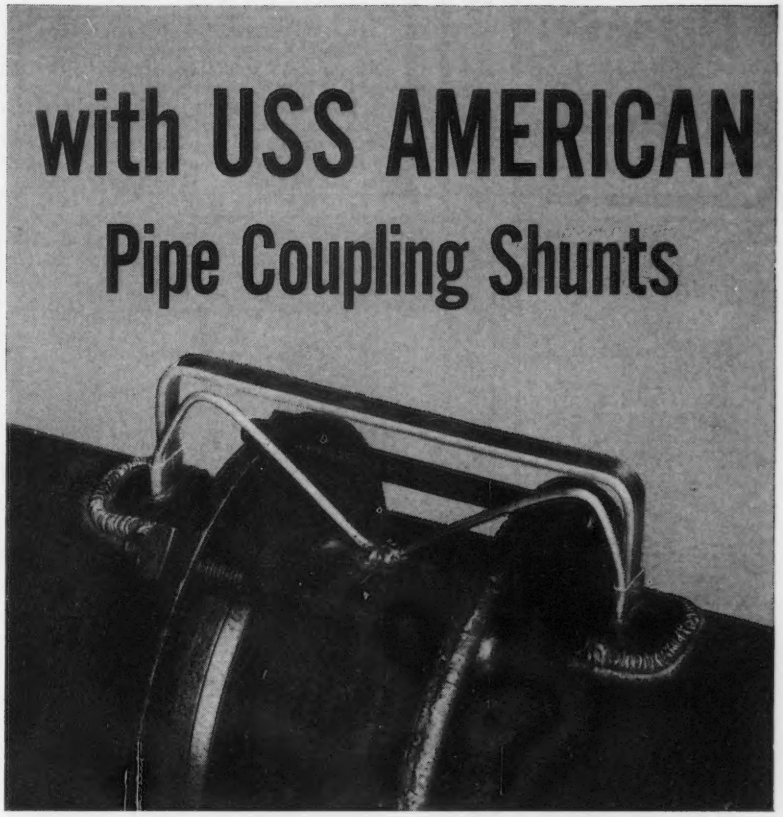

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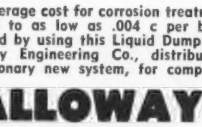

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hydrofluoric acid, concentrated hydrochloric acid and sulfuric acid and is lightly corroded by concentrated phosphoric acid and hydrogen peroxide. Against all other reagents, titanium is completely corrosion resistant and far superior to other materials. Graphs, 14 references.—INCO. 11749

6.3.17, 4.7

Observations on the Corrosion of Uranium in Liquid Sodium. (In English.) H. MOGARD. Paper before International Conf. on the Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF.8/P/787, July 12, 1955, 4 pp.

Microscopic, X-ray and microhardness techniques were used to study surface of uranium specimens after isothermal heating in liquid sodium for one month at 475 and 600 C. High purity uranium is attacked by oxygen impurity in liquid sodium up to 600 C. Uranium dioxide film forms on surface; growth rate depending on oxygen in sodium phase. When corrosion rate is 50μ per month, there is a 2-layer uranium dioxide film which is composed of an inside, dense and hard layer in contact with metal and an outside porous non-orientated layer. Calcium added to sodium acts as a corrosion inhibiting agent. In absence of uranium dioxide film, no corrosion was observed at 475 C. At 600 C smooth uranium dioxide film is broken with corrosion pitting of metal. Photomicrographs. —INCO. 11763

6.3.19, 3.8.4

Light-Figure Phenomenon Revealed and Crystal Planes Developed by Chemical Etching in Zinc Single Crystals. (In English.) MIKIO YAMAMOTO AND JIRO WATANABE. *Sci. Repts. Research Inst. Tohoku Univ.*, Sec. A, **7**, No. 4, 329-337 (1955).

The light figures revealed by and crystal planes developed on, zinc crystals etched by concentrated hydrofluoric acid, potassium hydroxide, sodium hydroxide, hydrochloric acid, dilute sulfuric acid or dilute ammonium persulfate or a saturated aqueous solution of cupric chloride are discussed; they can be classified into two main groups and the first group may further be divided into three subgroups.—MA. 11907

6.3.20, 1.4

Zirconium: A Bibliography of Unclassified Report Literature. HUGH E. VORESS AND THOMAS W. SCOTT, Compilers. Technical Information Service, U. S. Atomic Energy Commission, TID-3010 (Suppl. 2), Sept., 1955, 41 pp.

This supplement contains 228 annotated references to unclassified reports on zirconium which were available for review at the TIE from March 15, 1953, to September 20, 1955. Author, subject and report number indexes are included. (auth)—NSA. 11822

6.3.21, 1.6

The Metallurgy of Thorium and Its Alloys. O. N. CARLSON, P. CHIOTTI, G. MURPHY, D. PETERSON, B. A. ROGERS, J. F. SMITH, M. SMUTZ, M. VOSS AND H. A. WILHELM. Paper before International Conf. on the Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF.8/P/556, July 18, 1955, 89 pp.

Report covers occurrence of thorium and monazite processing; thorium metal preparation by thorium oxide and halide reductions and indium purification of thorium metal; physical and thermodynamic properties of thorium; melting and casting, heat treatment, recrystallization, effects of alloy additions on hardness; fabrication of thorium including forging and machining; powder metallurgy and properties of powdered thorium; mechanical properties; corrosion of thorium and its alloys; and summary of binary alloys of thorium with 35 elements including nickel (numerous equilibrium diagrams are presented). Section on corrosion presents data on corrosion behavior of thorium and its alloys in boiling distilled water, air, oxygen, nitrogen, argon, hydrogen, several molten metals and hydrofluoric acid. Tables, graphs, photomicrographs, 146 references.—INCO. 11789

6.3.20

The Oxidation and Corrosion Resistance of Zirconium. (In German.) WALTHER KOHLER. *Werkstoffe u. Korrosion*, 6, 329-331 (1955) July.

Extensive data on the physical and chemical properties of zirconium are tabulated. Some comparison values for titanium are included. The corrosion losses of zirconium in most inorganic and organic media are of the order of 0.000-0.075 mm per year. Concentration and temperature limits for losses in this range are given. In general, zirconium equals titanium in acid resistance and surpasses it in alkali resistance. At high temperatures, zirconium has great affinity for oxygen and nitrogen. The weight increase is negligible up to 315 C but increases to 3.68 mg per square cm per hour at 815 C.—PDA. 11888

6.4 Non-Ferrous Metals and Alloys—Light

6.4.3

Status of Beryllium Technology in the USA. A. R. KAUFMANN AND B. R. F. KJELLGREN. Paper before International Conf. on the Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF.8/P/820, June 28, 1955, 21 pp.

Covers source and availability of beryllium minerals; production, fabrication and reactor use of beryllium oxide; production of beryllium metal, ammonium beryllium fluoride, beryllium fluoride, metal reduction, vacuum casting and electrolysis of beryllium chloride; melting and casting techniques; fabrication methods including hot extrusion, rolling and forging; powder metallurgy, ductility and high temperature service; machining; corrosion; irradiation and beryllium health hazards. 20 references.—INCO. 11753

6.4.3, 3.5.8

Summarizing Report on Stress Corrosion of Beryllium. HUGH L. LOGAN AND HAROLD HESSIG. U. S. National Bureau of Standards, NBS-6, December, 1955, 11 pp.

Stress-corrosion tests on beryllium in a circulating 0.002 to 0.006 molar hydrogen peroxide solution at a temperature of 85 to 93 C. There was no evidence of stress-corrosion cracking in any of the specimens tested. Diagrams, photographs, micrograph, tables.—BTR. 11750

6.4.2

Age Hardening in Hydronalium Sheets. YOSHITSUGU MISHIMA. *Light Metals* (Japan), No. 17, 36-40 (1955) Nov. 10.

The fundamental studies on the age

hardening of Hydronalium alloys 52S and 56S were carried out to obtain some basic information on the problem of intercrystalline corrosion. Ageing processes at 400 C and 200 C were observed by measuring the changes in Vickers hardness and the results thus obtained were compared with those of binary aluminum-magnesium alloys and 3S alloy. A small peak found in the ageing curves at about 10 minutes from the beginning of ageing at 200 C has been discussed and the explanation proposed that the slight hardening is caused by the homogenization of strain which has been heterogenously distributed after quenching. Precipitation occurs locally first, followed by general precipitation and afterwards all-over-ageing can be observed when excess coalescence of the precipitates occures. Hardening occurs in 52S if quenched from 500 C but the hardening was found to occur chiefly at the grain boundary region. This seems to have an intimate relation with the intercrystalline corrosion problem whether the hardening is caused by local precipitation at the grain boundaries or by the enrichment of magnesium atoms at the boundary region. The slight hardening called "first peak" as mentioned above is discussed.—ALL. 11765

6.4.2

Preparation of and Ways of Protection of Aluminium Surfaces Against Corrosion. I. M. TRPKOVIC *Zastita Materijala*, **3**, No. 3, 99-106 (1955).

Instructions are given regarding the preparation of aluminum surfaces for further protection. The processes of anodic oxidation, phosphating, galvanization and electro-plating of aluminum surfaces are described.—RPI. 11862

6.4.2

Corrosion of Aluminum and Its Alloys. (In Czech.) B. PUCHNAR. *Strojirenstvi*, **5**, No. 8, 605-608 (1955) August.

Intercrystalline, spot and uniform corrosion; effect of various metals and electric current; corrosion caused by inorganic salts, building materials and impregnation preparations; criteria for choice of materials in contact with aluminum parts. Tables, diagrams.—BTR. 11858

6.4.2

The Behaviour of Aluminum in Buffer Solutions. (In German.) A. R. TOURKY, W. MACHU AND K. HUSSEIN. *Aluminium*, **31**, No. 12, 599-604 (1955) Dec.

Effect of hydrogen ions (using buffer solution) on the oxide film on pure aluminum (99.99%). After short exposure to acidic buffer solutions, pH 4-8, the porosity of the oxide film is reduced to a very low level; even in alkaline solution pH 8-11 formation of protective film occurs in 1-2 days. Protective film formation promoted by phosphate ions and inhibited by chlorine, particularly in alkaline solution; cathodic pretreatment loosens natural oxide film, slightly more so in acid than alkaline solutions. —BNF. 11849

6.4.2, 3.7.3

Study of Riveting Materials for Aluminum Alloys. H. YAMAGUCHI AND J. YAMAMOTO. *Light Metals* (Japan), No. 17, 41-46 (1955) Nov. 10.

Mechanical properties, electrode potential and corrosion resistance of aluminum riveting materials were studied. Corrosion resistance of 52S and NR5 was good; 54S, 56S and NR6 had poor corrosion resistance. Considering both mechanical properties and corrosion resistance, NR5 was recommended as the rivet material for ANP plate.—JSPS. 11906

6.4.2, 4.6.1

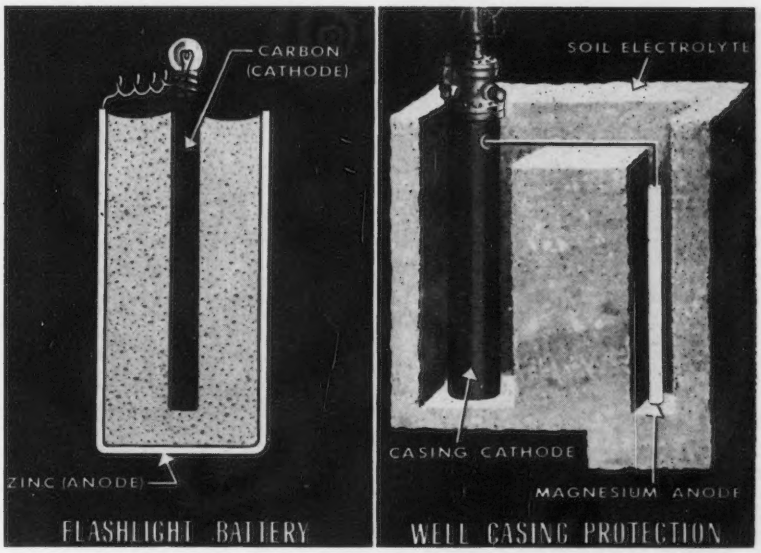
Corrosion of Aluminum and Aluminum Alloys in Aqueous Solutions at High Temperatures. (In English.) K. CARLSEN. Paper before Internat. Conf. on the Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF.8/P/880, June 29, 1955, 13 pp.

Tests at 230 C to select suitable materials for pressurized water. Highly dispersed silicon as an alloying element, of a content corresponding to the solid solubility limit at the eutectic temperature, makes aluminum (2S) resistant to corrosion. Aluminum-silicon and aluminum-iron-silicon alloy were the most promising of the alloys studied. Dichromate silicate mixtures as inhibitors protect aluminum in high temperature water. Tables show: rate of weight change of commercial aluminum alloys in distilled water at 230 C; effect of additions of alloying elements on the corrosion of super purity aluminum in distilled water; effect of surface treatment on corrosion of 2S aluminum in distilled water at 230 C; and effect of additions to distilled water on corrosion of aluminum at 230 C. 9 references.—INCO. 11791

6.4.4

Corrosion and Protection of Magnesium Alloys Containing Zirconium. H. G. COLE. Gt. Brit. Royal Aircraft Establishment, Technical Note. Met 222, June, 1955, 17 pp.

Results of sea-water-spray corrosion



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tests on magnesium alloys containing 0.78-1.02% zirconium showed that their corrosion resistance is similar to that of ordinary purity magnesium alloys. Chromate treatment alone gave little protection to the magnesium-zirconium alloys, but when followed by paint its effectiveness equaled that of magnesium-aluminum alloys.

The MEL (Magnesium Elektron Ltd.) chrome-manganese bath used under conditions in which a dark-brown film was deposited, gave approximately the same results as the hot half hour bath (iii) prepared according to British Specification DTD 911A for pickling and chromate baths. High purity magnesium alloys displayed high corrosion resistance, both in cast and sheet form.—PDA. 11777

6.4.4

Corrosion Protection of Magnesium MAURICE HARDOUIN. *Metal Ind.*, **87**, No. 20, 408-409 (1955) November 11.

In this concluding part of a series of articles on the corrosion protection of magnesium the application of a primer having inhibiting properties and that of the proper paint coatings is discussed. The film obtained on magnesium by pickling has to be tenacious and degreasing should be carried out carefully. As primer, zinc chromate is recommended. It is stated that if the operations are properly carried out and a suitable primer and paint, such as one of synthetic resin base, for example, are used full protection of the metal can be obtained.—ALL. 11805

6.4.4, 2.3.9

Formation and Application of Oriented Figures Obtained on Magnesium by Sublimation. L. GRALL. *Rev. Met.*, **52**, No. 8, 603-610; disc., 610-611 (1955).

Corrosion figures are ordinarily obtained by chemical or electrolytic attack and also by thermal etching. Grall developed a method of obtaining true sublimation figures on pure magnesium containing iron 17, aluminum 70, copper 6, and chlorine 35 ppm and on a magnesium alloy containing aluminum 4500 and beryllium 80 ppm. The metal was heated to 550-650 C for ~15 min. in high-purity argon or to ~500 C in argon at a pressure of 10^{-4} mm Hg for some hours. The sublimation produces isolated geometrical figures oriented parallel to the (0001) faces. Displacement of the grain boundaries due to this treatment was observed. Since sublimation figures depend on the existence of a layer, e.g. of oxide, on the surface of the metal, Grall studied the behavior of the surface of specimens previously oxidized under various conditions. He found, for instance, that the oxide formed at 350 C is protective, while that formed at 450 C is not. The oxide layer formed at 500 C only imperfectly covers the metal and where it is thin, sublimation figures are observed. 7 references.—MA. 11831

6.4.4, 3.5.8

Stress-Corrosion Mechanism in a Magnesium-Base Alloy. D. K. PRIEST, F. H. BECK AND M. G. FONTANA. *Trans. Am. Soc. Metals*, **47**, 473-487; disc., 487-492 (1955).

An investigation of the mechanism of stress corrosion-cracking in extruded magnesium-6% aluminum-1% zinc-02% manganese alloy in 3% sodium chloride-3% potassium chromate solution. When the grain size exceeded a certain value cracking was transgranular. Below this size it was trans- or intergranular depending on the heat treatment. Variation in pH of the solution did not affect the mode of cracking. Stress corrosion could be stopped by cathodic protection. Stress corrosion is considered to be connected with the presence of FeAl in certain planes.—BNF. 11857

6.6 Non-Metallic Materials

6.6.4

Oxidation Studies of Some Natural Graphites. R. A. HEINDL AND N. F. MOHLER. *J. Am. Ceram. Soc.*, **38**, No. 3, 89-94 (1955) March.

Oxidation rates for 20 natural flake and amorphous graphites were determined at 900 C and numerical constants for oxidation rates under specific conditions were established. Methods of analyses are given.—BL. 11788

6.6.6

The Chemical Resistance of Molybdenum Disilicide as a Material. (In German.) E. FITZER AND J. SCHWAB. *Metall*, **9**, No. 23/24, 1062-1065 (1955) Dec.

Molybdenum disilicide melts above 2000 C. Sample produced by powder metallurgy was stable towards lead, tin and zinc but reacted with aluminum, copper and the iron group. At 1400 C in oxygen an adhesive glassy film is formed. Molybdenum disilicide is stable to sulfurous gases at 1000, but not to chlorine, though the glassy film protects it against hydrogen chloride gas. Aqueous mineral acids do not attack or only slightly. It appears to be a promising material for chemical and metallurgical plant when fabrication difficulties have been solved. 16 references.—BNF. 11733

6.6.6, 6.7.2, 8.4.5

Recent Developments in the Technology of Ceramic Materials for Nuclear Energy Service. J. M. WARDE AND J. R. JOHNSON. *J. Franklin Inst.*, **260**, 455-466 (1955) Dec.

Recent developments in the technology of ceramic materials are reviewed. Data on uranium oxides are summarized. Thorium oxide is discussed as a potential breeder material. The fabrication of cermets is also briefly discussed. Radiation effects and corrosion of ceramics are reviewed.—NSA. 11859

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1, 3.5.8

The Life of Ball and Roller Bearings. R. H. WARRING. *Machinery Lloyd* (Overseas Ed.), **27**, 69, 71, 72 (1955) Dec. 3.

Various factors of failure with particular attention to fretting corrosion. An empirical formula to determine expectant life is presented. Table.—MR. 11856

7.1, 8.9.4

Railroad Diesel Fuels and Lubricants. *Lubrication*, **41**, No. 11, 121-132 (1955) Nov.

Problems in lubricating oil performance for Diesel locomotives including ring sticking and breakage, valve sticking and blowing, wear, metal corrosion (including silver), general engine cleanliness, viscosity buildup and oil contamination. Diesel bearing materials are discussed and their load carrying capacity, hardness, fatigue strength, antiseizure, conformability and embeddability properties are tabulated. Bearings include copper-lead, silver, aluminum and lead-bronze types. Factors causing corrosion, erosion and abrasion are considered. Types of fuels are discussed and fuel performance characteristics compared. Most significant differences between 50 centane distillates fuel and residual distillate blend were corrosion and pitting of exhaust valves and seats by residual distillate fuel as shown by laboratory tests. Table lists amounts of vanadium, iron, nickel and sodium present as trace elements in residual fuel. Tables, photomicrographs, graphs, illustraitons.—INCO. 11745

7.3 Pumps, Compressors, Propellers, Impellers

7.3

Steels, Cast Irons, and Miscellaneous (Copper-Nickel) Alloys for Casting Pump Components Resistant to Abrasion or Corrosion. R. POIROT. *Rev. gen. Mecan.* (N.S.), **39**, No. 75, 76-84 (1955).

A general review of the use of cast irons for pump parts where abrasion-resistance is the primary material requirement or of austenitic cast iron (Ni-Resist), 18:8 stainless steels, or cupro-nickels where corrosion-resistance is the more important factor.—MA. 11850

7.4 Heat Exchangers

7.4.1, 4.6.2, 7.7

The Effect of Surface Material, Surface Finish, Temperature of Operation and Water Composition on the Deposition of Carbonate Scale on Electric Immersion Heaters of High Specific Loading. M. V. GRIFFITH AND H. M. BROWNING. ERA Tech. Rep. Y/T16, 1951 (published 1955), 34 pp. British Electrical and Allied

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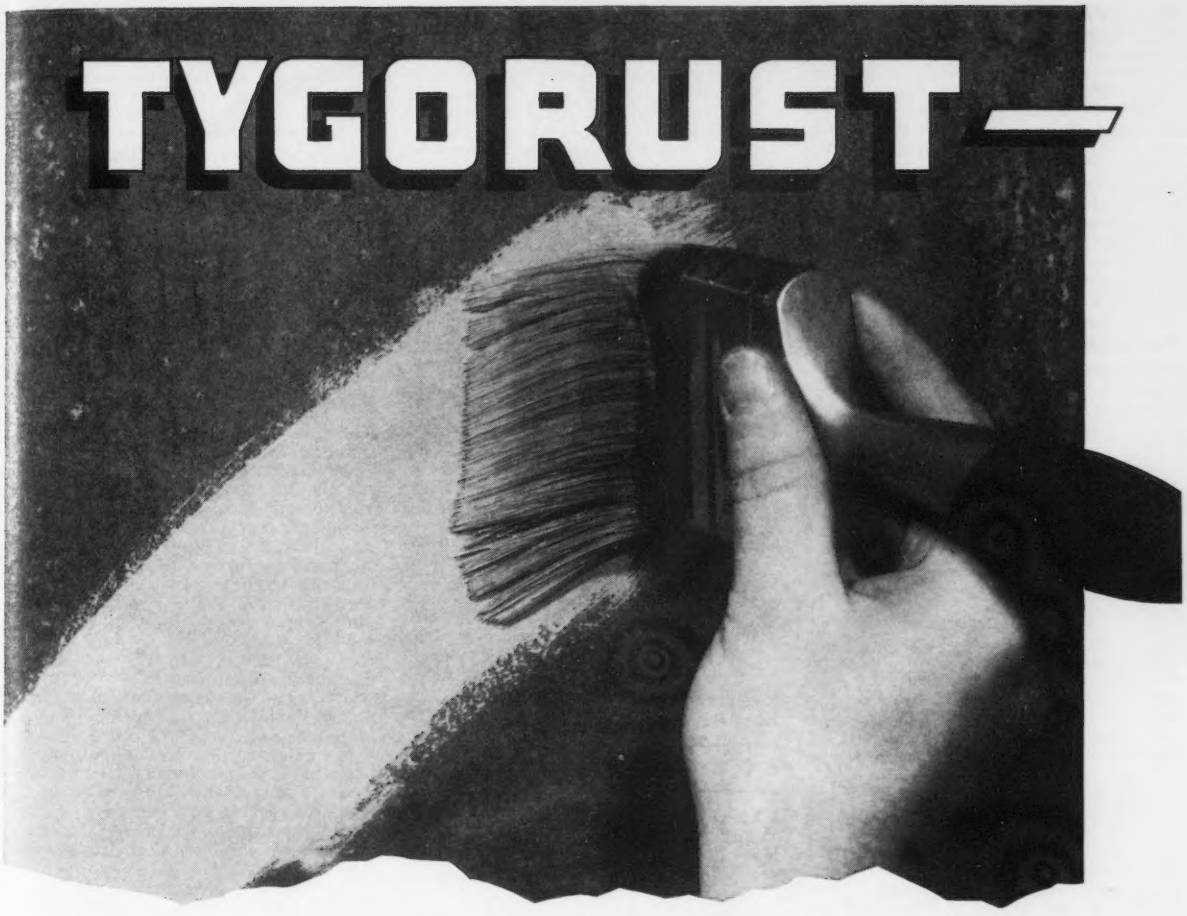

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Laboratory tests and full-scale service trials with heaters having various types of surface: gold, silver, rhodium, chromium, nickel and tin electrodeposits (matt and polished) on copper; graphite on copper; Monel. Neither surface material nor surface finish had any useful effect on the rate of scale deposition, but chromium plating is recommended, since it reduces the adherence of the scale and improves corrosion resistance. Scale formation was not affected by use of radio frequency currents.—BNF. 11797

7.6 Unit Process Equipment

7.6.6

Review of Digester Corrosion Causes. W. B. Parker. *Tappi*, **38**, No. 5, 261-264 (1955) May.

Several causes of digester corrosion are outlined with solutions in some cases. Work of Tappi Digester Corrosion Subcommittee is referred to. 11762

7.7 Electrical—Telephone and Radio

7.7, 3.8.4, 6.3.6

Effect of Electric Field on Oxidation of Copper. (In English.) H. H. Uhlig and A. E. Brenner. *Acta Metallurgica*, **3**, No. 1, 108-109 (1955) Jan.

A letter. A condenser was constructed from commercial copper in such a way that one of the plates could be maintained accurately at a temperature of 150 C while dry air was circulated over it. The rate of oxidation of this surface was measured while positive and negative electrostatic fields of up to 15,500 V/cm were applied across the condenser. The surface was prepared by filing and the amount of oxide determined by electrolytic reduction using the principle of coulometry. Without a field, the oxidation rate was given by $T = k \log (1 + t/\tau)$, where T is the oxide thickness in Å., k = 424 Å., and $\tau = 1.6$ min. No effect of the electric field could be detected.—MA. 11913

7.7, 5.4.8

Navy Finds Organic Finishes Aid in Protecting Selenium Rectifiers Against Mercurial Fungicides. G. W. Grupp. *Org. Finishing*, **16**, No. 3, 14-15 (1955).

Oleoresinous varnishes and waxes were not promising coating materials for the protection of selenium rectifiers against the vapors of mercurial fungicides. Coatings containing organic polysulfide and vinyl resin combinations were very effective.—RPI. 11742

7.7, 6.3.21

Effect of Different Corrosive Agents on Germanium. Part II. Physical Considerations. (In German.) Gotthold Zielasek. *Z. Metallkunde*, **46**, 229-233 (1955) March.

In an attempt to utilize the results of the foregoing study to improve the understanding and performance of germanium transistors and diodides, variously surface-etched germanium samples were studied by means of potential measurements. Treatment with carbon dioxide gas at 850 C resulted in structural etching accompanied largely by a transformation of *n*-type germanium into the *p*-type.

Potential measurements on the surface of polycrystalline germanium showed jumps of several hundred ohmcentimeters in electrical resistance, occurring at the grain boundaries, whereas monocrystalline germanium displayed an even resistance-distribution pattern. In the usual measurement of electrical resistance on polycrystalline semiconductors, the potential differences at the grain boundaries must, therefore, be taken into account.

When selecting semiconductors for current rectifiers, the expected service life of the electricity charge carrier must be known in addition to the ohmic resistance. Life expectancies can be calculated, e.g., by the well-known Morton-Haynes method. Polycrystalline germanium shows a lower lifetime than does monocrystalline material.—PDA. 11875

7.7, 8.2.2, 8.2.1

Corrosion and Corrosion Prevention of Electrical Equipment. Parts I, II. (In German.) B. Muller. *Energietechnik*, **5**, Nos. 9, 10, 406-412, 444-451 (1955) Sept., Oct.

Part I. Description of causes and mechanisms of corrosion, erosion and cavitation; bacterial corrosion and influence of temperature; method of corrosion measurement and its prevention. Diagrams, micrographs, table.

Part II. Types of corrosion phenomena on power-equipment, turbines and related apparatus; the use of cathodic protection. Diagrams, graphs, tables. 6 references.—BTR. 11837

8. INDUSTRIES

8.4 Group 4

8.4.3

The Problem of Corrosion in Petroleum Refining. Part I. E. J. M. Tait. *Corrosion Prevention and Control*, **2**, 25-30, 44 (1955) Dec.

Nature of and an approach to solving the external and internal corrosion. (To be continued.)—MR. 11844

8.4.5

Metallurgical Research in Nuclear Power Production. J. G. Ball. *J. Inst. Metals*, **84**, Pt. 7, 239-250 (1956) March.

Range of metals of special interest in nuclear energy; features of reactors which influence metallurgical problems; latter are discussed under following headings: irradiation stability, thermal stability, sheathing materials, corrosion, fabrication and alloying and physical properties. 21 references.—BL. 11867

8.4.5

Liquid Metal Fuel Reactor. F. T. Miles and C. Williams. Paper before International Conf. on the Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF.8/P/494, July 18, 1955, 16 pp.; Fluid Handling, No. 70, 319-320 (1955) Nov.

Describes a 210,000 KW plant in which reactor uses a uranium-bismuth solution fuel. The uranium-233 is produced in reactor from thorium which surrounds graphite reactor core in breeder blanket. Both uranium-bismuth fuel solution and thorium bearing fluid are circulated for heat removal and chemical processing. 2¼ chromium-1 molybdenum steel (Croloy 2¼) is used for the container pressure vessel, connecting piping, main reactor cooling loop and sodium heat exchanger as well as all vessels and transport lines that are in contact with uranium-bismuth, sodium and NaK. Croloy 2¼ resists corrosion of sodium and NaK at 600 C provided oxygen does not exceed .02% and it has excellent creep and strength properties at operating temperature of 550 C. Chief corrosion problem of mass transfer is solved by additions of magnesium to pick up traces of oxygen and of zirconium to inhibit rate of dissolution of steel in high temperature region and deposition in low temperature region of liquid metal system. Tables, diagrams.—INCO. 11767

8.4.5

A Survey of Irradiation Effects in Metals. J. W. Glen. *Advances in Physics* (Quart. Supplt. of Phil. Mag.), **4**, No. 16, 381-478 (1955) October.

A full survey of knowledge based apparently on a complete bibliography (the latter occupying 12 pages); effects on physical, mechanical and structural properties are considered.—BNF. 11784

8.4.5

Initial Studies on the Effect of High Level Gamma Radiation on Corrosion of Metals. F. Hittman and O. A. Kuhl. Brookhaven National Laboratory. U. S. Atomic Energy Commission Pubn. BNL-2257, July, 1955, 24 pp.

Considers various structural materials in corrosive chemical systems from room temperature to 500 C. Diagrams, graph, photographs, micrographs. 10 references.—BTR. 11790

8.4.3, 5.8.2, 1.2.2

Studies of Corrosion Control of Pumping Wells. I. Uehara. *Corrosion Engineering*, **4**, No. 6, 266-269 (1955) December.

Amine-type corrosion inhibitors have been used for protecting the pumping wells in In-nai and Niitsu oil fields. A study was made on comparing the statistical sum up of the material replacements in the inhibited period to the non-inhibited one.

The survey indicates that the use of inhibitors has resulted in a 50% decrease in material replacements.—JSPS. 11917

8.4.5, 4.7

The Metallurgy of Reactor Fuels. J. P. Howe. Paper before International Conf. on Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF. 8/P/825, August, 1955, 46 pp.

Solid fuels, including uranium slugs are spaced in stainless steel tube with liquid NaK filling space between fuel and stainless steel cladding. Dispersion of fuel materials occurs in metallic matrices: austenitic steel-uranium dioxide dispersions. Thermal fatigue probably places limit on number of times reactor may be started and stopped. At 400 C stainless steel will fail after a few hundred cycles at bending or thermal stresses corresponding to a heat flux of 300 watts/cm² through a thickness of 0.01 in. Thorium-uranium cylinders were contained in NaK- or sodium-filled stainless steel tubes. For all but liquid bismuth-uranium alloys, austenitic stainless steel is recommended; for this alloy, Croloy 2½ is suggested. Notes are given on materials and processes involved in manufacture of atomic fuels. Interdiffusion of fuels and cladding materials is discussed; data on Type 347 stainless in contact with uranium given.—INCO. 11893

8.5 Group 5

8.5.3

The Corrosion of Steel in White Liquor: Communication from Norwegian Sulfate Corrosion Committee. (In Eng-

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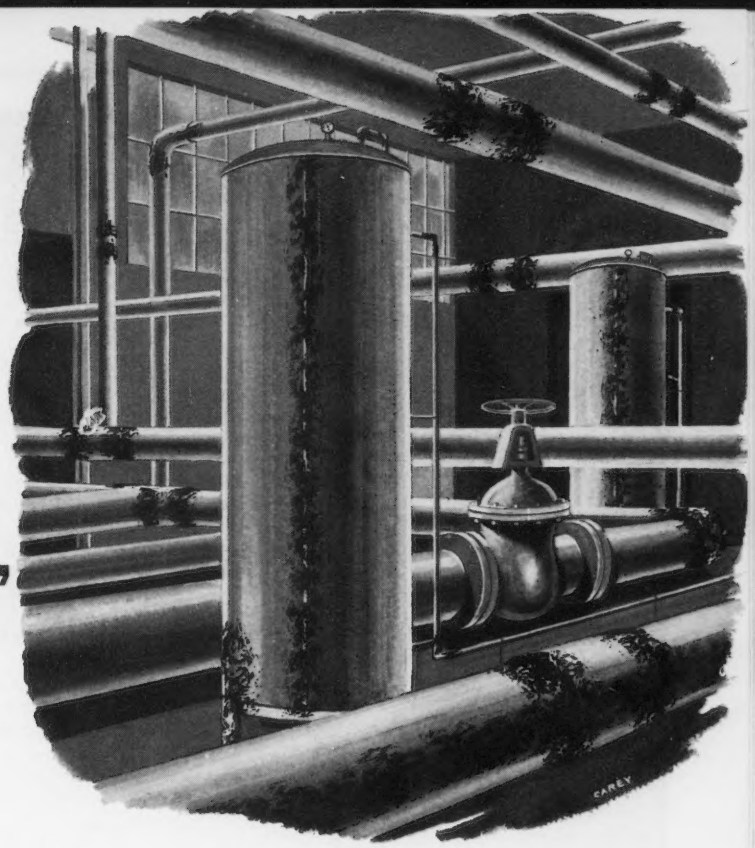

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lish.) B. HAEGLAND AND B. ROALD. *Norsk Skogind.*, **9**, 351-364 (1955); Paper Industry, **37**, No. 10, 972 (1956) Jan.

Corrosion was studied by polarization experiments and determination of weight loss. Steel corrosion is caused by sodium polysulfides in the liquor and involves formation of ferrous ions which are precipitated as ferrous sulfide, while an equivalent amount of polysulfide is reduced to sulfide ions by excess of electrons on the corroding steel surface. Amount of polysulfides is determined by an equilibrium between polysulfide-, sulfide-, sulfite- and thiosulfate ions, as indicated by $Na_2S_2O_3 + Na_2S = Na_2SO_3 + Na_2S_2$. Concentration of sodium hydroxide affects corrosion by determining the concentration of unhydrolyzed sodium sulfide in the liquor. Corrosion rate is determined by the rate at which polysulfide ions are transported to the steel surface. They come partly from the bulk of the solution by diffusion through the layer of ferrous sulfide and in part by the reaction between sulfide and thiosulfate within the diffusion layer. Corrosivity of the liquor is proportional to the product of the concentrations of thiosulfate and sulfide, with a suitable adjustment for the action of sodium hydroxide on the sodium sulfide. Corrosive action is decreased by increasing the concentration of sodium sulfite. High concentrations of polysulfides inhibit corrosion by promoting passivation of the steel.—INCO. 11801

8.6 Group 6

8.6.3

Surface Protection of Materials in Machine Construction. B. VAN DER BRUGGEN. *Werkstoffe u. Korrosion*, **6**, No. 5, 223-227 (1955) May.

Corroded and contaminated cast iron surfaces and their causes are discussed. Surface pretreatment and finishing techniques and plant layout are described for machine parts, with special reference to looms.—RPI. 11910

8.7 Group 7

8.7.2

Symposium on the Corrosion of Instruments in Relation to Design, Manufacture, and Application. *Trans. Soc. Instrument Technology*, **7**, No. 3, 123-135 (1955) Sept.

Papers presented are: Scientific Basis of Corrosion, U. R. Evans (pp. 123-124); Design of Instruments: Selection of Material for Aircraft Instruments, J. G. Walford (pp. 124-127); Manufacture of Instruments, G. W. Balls (pp. 127-129); Applications of Instruments, C. Lamond (pp. 129-132: deals with maintenance and protection of instruments in chemical works).—BNF. 11861

8.9 Group 9

8.9.1, 3.5.8

Fatigue of Aircraft. P. L. TEED. Shell Aviation News, No. 208, 14-21 (1955) October.

After reviewing the history of the occurrence of fatigue in aircraft, considers the stresses imposed when standing on the ground, during take-off and landing and in flight; influence of stress concentration, scatter, built-in stresses, and prestressing.—BNF. 11846

8.9.4, 4.4.7, 7.1

Railroad Motive Power—and Corrosion: Topic of the Month. S. K. COBURN. Assoc. Am. Railroads. *Corrosion*, **12**, No. 4, 155t-156t (1956) April.

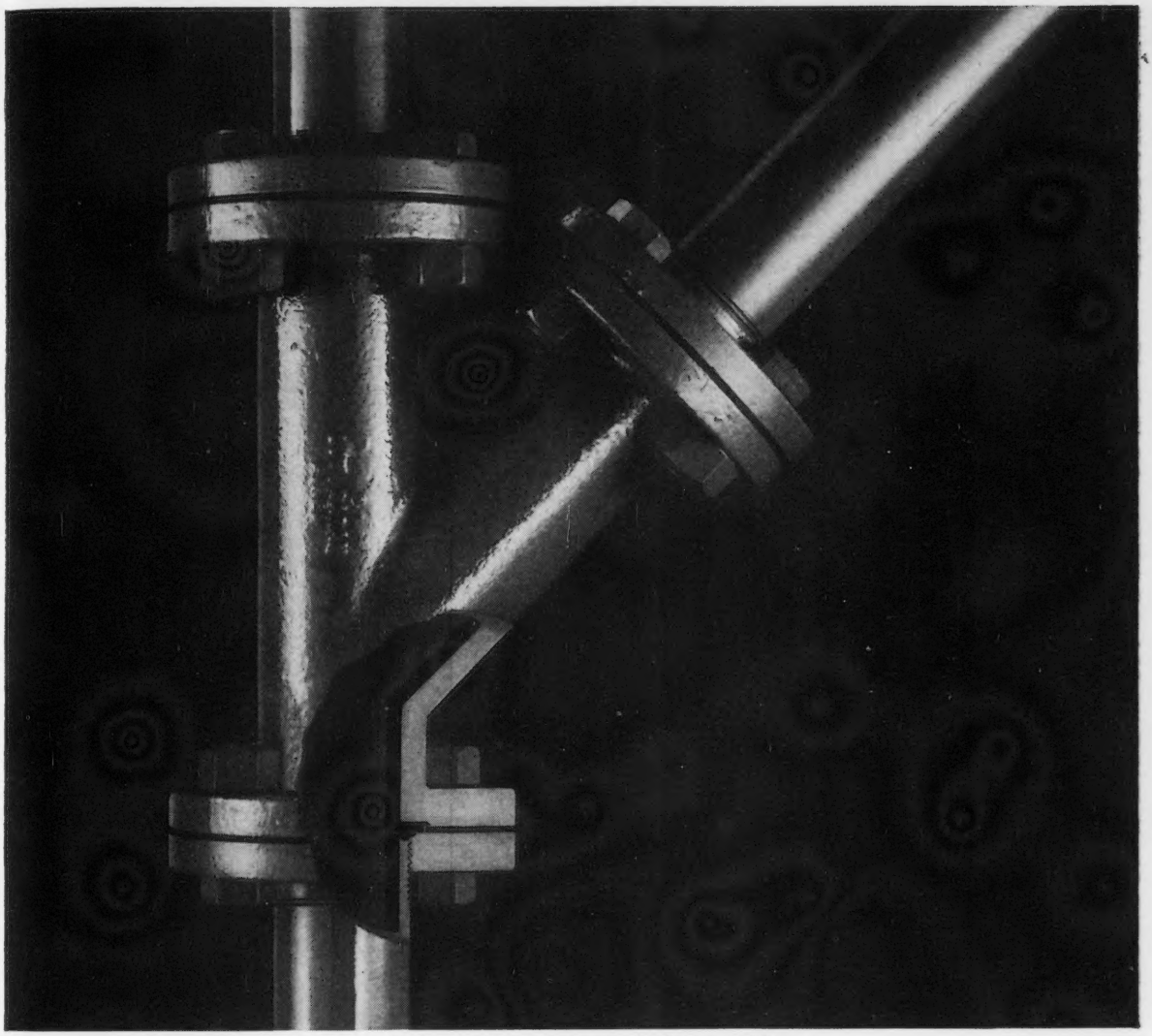
High cost lubricating and fuel oil needs and corrosion problems in Diesel locomotives have resulted in the use of lower cost residual oil fuels and corrosion inhibitors. Residual oil fuels contain elements present in concentrated form in crude oil accompanied by active polymerizing systems which cause corrosion. In fuels containing more than 0.5 sulfur, sulfur acids become a combustion product corroding liners, rings, valves and pistons. Where copper fuel lines and sintered bronze filters are in use copper corrosion develops from the presence of free sulfur and complex polysulfides. The cooling system creates cavitation erosion, crevice corrosion and corrosion due to galvanic couples. The gas turbine-electric power plant locomotive uses a low cost fuel oil containing ash formers such as vanadium, sulfur and sodium which cause the formation of sodium sulfate and vanadium pentoxide which corrode many alloy systems. Corrosion conditions can be minimized by specifying a fuel with a vanadium to sodium ratio and a vanadium to calcium ratio. Constant improvement in design and inhibitor formulation is controlling corrosion and fuel costs.—INCO. 11841

8.9.5, 5.4.8, 1.6

Ship Bottom Coatings and Ship Painting Remedies. (In German.) MANFRED RAGG. Book, 1955, 412 pp. WILHELM PANSEGRAU VERLAG, Uhlandstrasse 102, Berlin-Wilmersdorf, Germany.

A revised and expanded edition of an earlier work (1925). Thorough examination of the theoretical and practical aspects of coatings used on interior and exterior surfaces of ships. Data are given on formulations, application methods, including primers, cathodic protection, effect of marine life, organic and inorganic coatings, laboratory methods of testing materials and numerous other activities involved in protecting ships against corrosion.

There are alphabetical subject and author indexes. 11729



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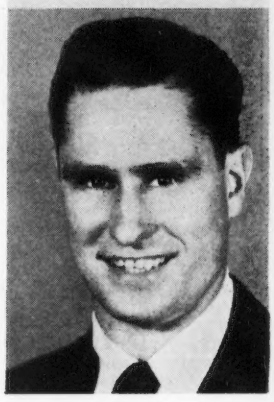

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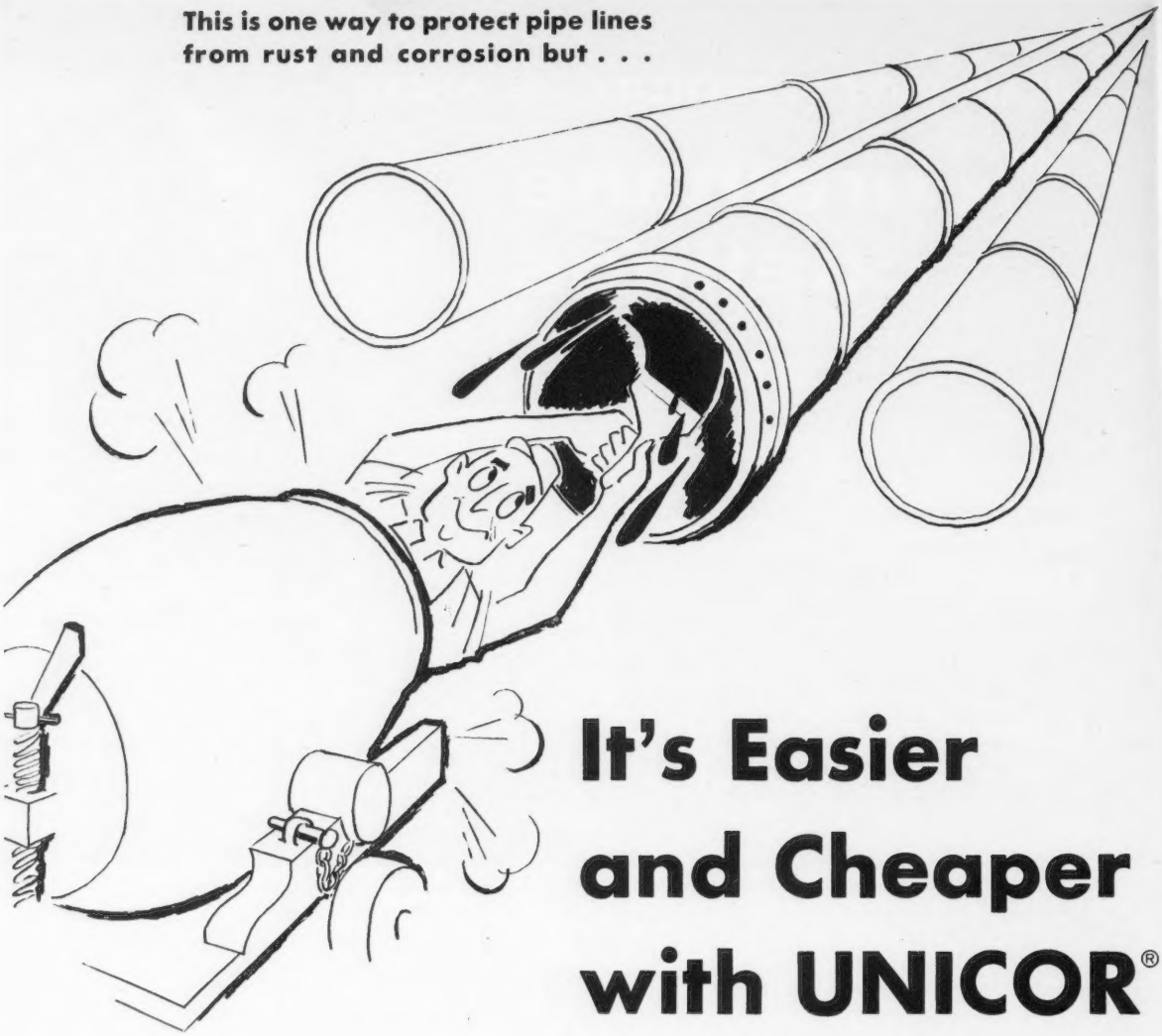

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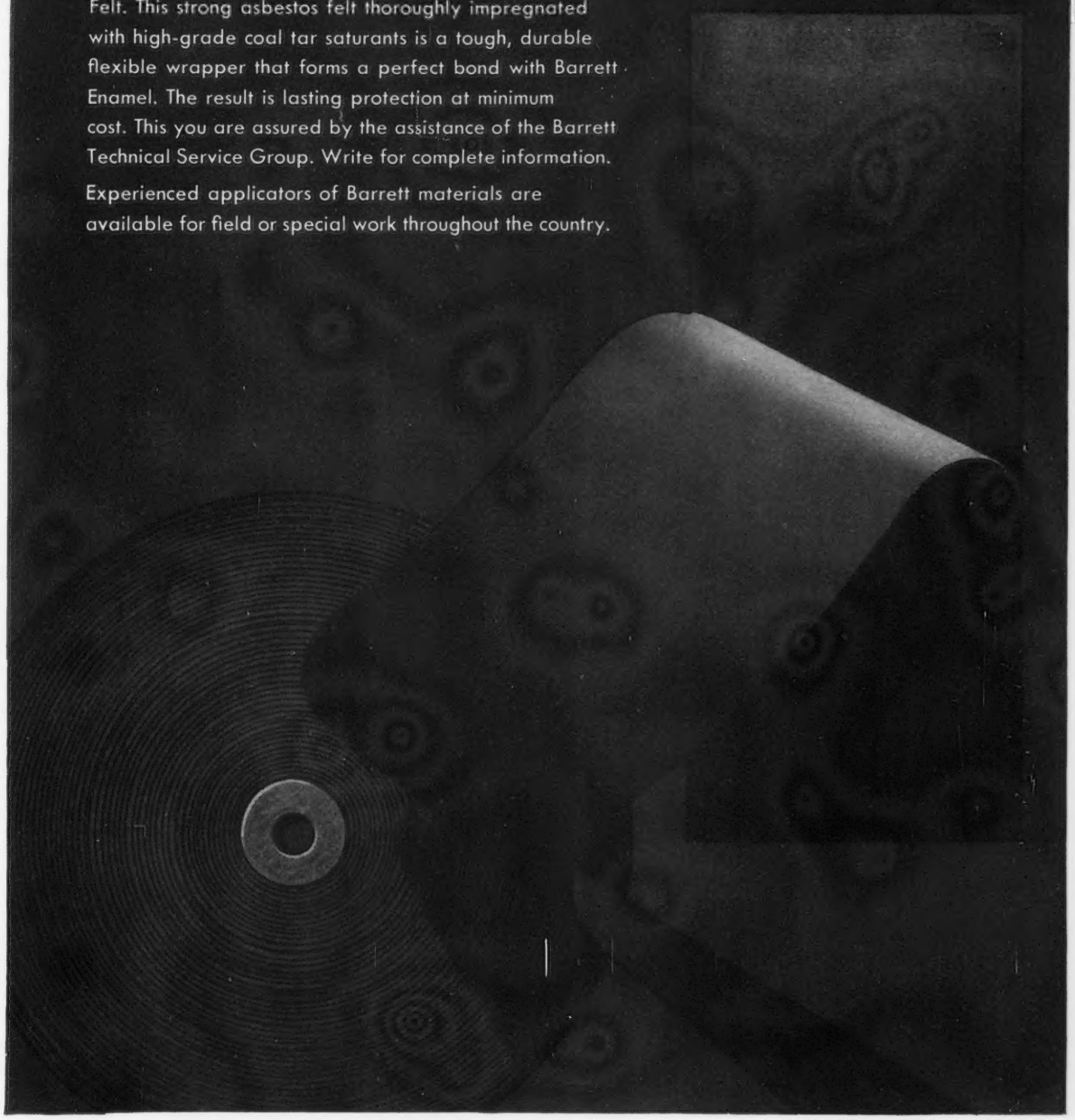

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2	3181	½	0.086	0.20 to 0.27
3	3600	2	0.300	0.22 to 0.30
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5	3400	1 ½	0.240	0.22 to 0.30
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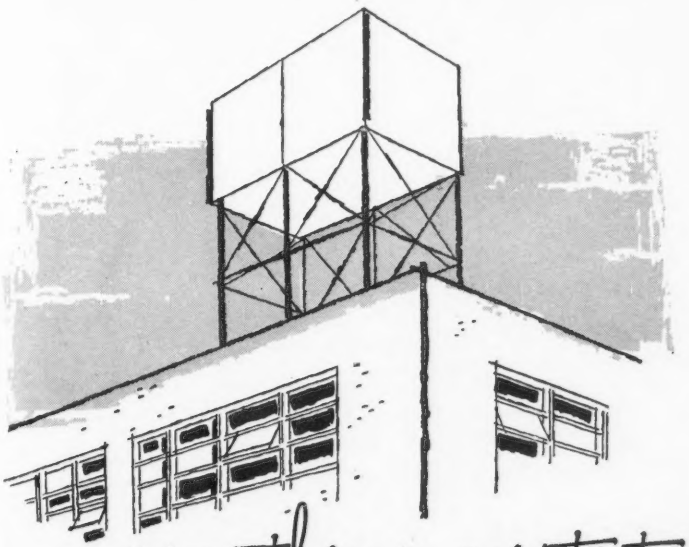

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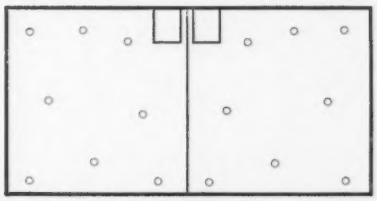

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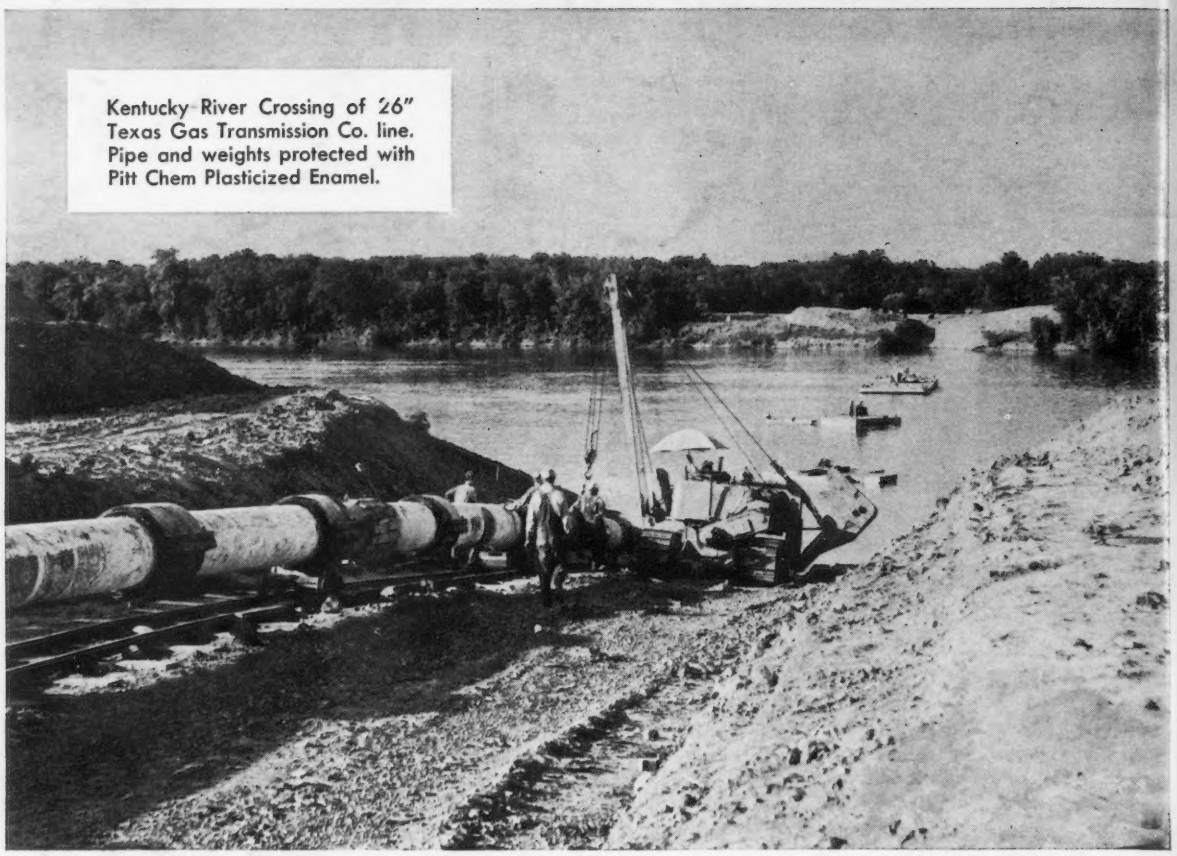

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